Reducing DoD Product Development Time: The Role of the Schedule Development Process

Major Ross T. McNutt, Ph.D.
Acquisition Management Policy Division
Assistant Secretary of the Air Force (Acquisition)

Lean Aerospace Initiative
Massachusetts Institute of Technology

December 1998

The research on reducing DoD product development time was made possible through support of the Massachusetts Institute of Technology as part of the Air Force and industry sponsored Lean Aerospace Initiative. The research was conducted by Major Ross McNutt while on the Air Force Graduate Fellowship Program through the Air Force Institute of Technology. Major McNutt is assigned to the Acquisition Management Policy Division in the office of the Assistant Secretary of the Air Force (Acquisition). Major McNutt runs the Air Force Cycle Time Reduction Program which is implementing his recommendation. Current information is available at www.safaq.hq.af.mil/acq_ref/cycletime.

This dissertation has been edited from its original form for grammatical errors.
RTM 1 May 2000

Reducing DoD Product Development Time: The Role of the Schedule Development Process

by

Ross McNutt

B.S. United States Air Force Academy, 1987
M.S. Technology and Policy, MIT, 1992
M.S. Aeronautics and Astronautics, MIT, 1992

Submitted to the Department of Aeronautics and Astronautics
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY
at the
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

December 1998

Author..

Technology, Management, and Policy Program
Program in Science and Technology for International Security
December 1998

Certified by...
Kosta Tsipis
Director, Program in Science and Technology for International Security

Certified by...
John Deyst
Professor, Department of Aeronautics and Astronautics

Certified by...
Earll Murman
Professor, Department of Aeronautics and Astronautics

Accepted by...
Richard de Neufville
Chairman, Technology, Management, and Policy Program

Note: This dissertation has been edited from its original form for grammatical errors.
RTM 1 May 00

Reducing DoD Product Development Time: The Role of the Schedule Development Process

Abstract

According to the Packard Commission, “Unreasonably long acquisition cycles -- ten to fifteen years for major weapon systems is a central problem from which most other acquisition problems stem.” Since the commission issued its report in 1986, the time required to develop new military systems has only grown. This research and its recommendations are intended to identify and eliminate the causes of those long development times for military systems. This report addresses a key factor in determining the development time for military projects: the project’s initial schedule. Part 1 outlines the current situation, previous efforts to reduce development time, and experiences with cutting development time in the commercial sector. It also documents the military product development process. Part 2 identifies a key area--the schedule development process, and its impact on development time--for in-depth research. Through understanding what is driving the initial project schedule and the impact of the initial project schedule on the eventual development time, the author identifies key drivers of development time. Part 3 presents the results of three surveys and analyzes the processes used to develop a project’s initial schedule, the process used to develop a contracted schedule, and the impact of these schedules on actual development time. Part 4 presents observations, draws conclusions, and makes specific recommendations for remedial action.

The key barriers to reducing development time for military systems are the lack of importance placed on project schedules; the lack of effective schedule-based information and tools; the lack of schedule-based incentives; and the overriding impact of the funding-based limitations on defense projects. The steps necessary to establish a focus on reducing development time are: 1) recognizing the impact of development time, 2) providing the necessary information for decision makers, 3) providing proper incentives at each organizational level, and finally providing a structure to effectively manage the set of all development projects to ensure that each project can be funded based on its development-related requirements.

Implementing the recommendations and focusing on reducing development time will force other changes in the acquisition process. The focus on reducing the time to develop and field systems will drive the acquisition system to better meet the needs of our warfighters, more rapidly, and at lower cost. Better, Faster, and Cheaper. Even more importantly, shortening development times is critical to develop and produce, with limited resources, the right weapons at the right time to deter or to defeat any potential enemy at any time with the minimum cost to our warfighters.

Prologue and Overview

The U.S. Department of Defense spearheads the world's largest product development operation. In 1997 alone it spent $32.5 billion developing new or improved military systems. In the past 20 years DoD has spent the 1998 equivalent of $732.5 billion on researching, developing, testing, and evaluating new systems. Through these critical activities, the DoD creates the equipment its forces need to fight and win. An effective product development system should ensure that those forces have the right weapons at the right time in the right quantity to deter any potential enemy.

Product development activities determine which systems will be built, what capabilities they will have, how reliable they will be, when they will be available, and how much they will cost. Product development also influences how many systems are fielded, how the systems can be employed, and how they will be maintained. Improving the performance of the DoD product development system could result in more effective weapon systems, acquired at lower cost, in a shorter time.

Over the last 10 years, companies in a wide array of industries have made dramatic improvements in their approaches to creating new products, largely by focusing on cutting development time. Companies with this focus often achieve 50% to 70% reductions by forcing continuous improvement across their entire organization. The result is higher-quality products that are easier to manufacture, that are ready for market faster, and that can be sold for a higher profit. These companies have also dramatically increased the number and variety of products they manufacture. Development time is a key component of a company's ability to meet customers' changing needs. Many companies and industry leaders see shorter development times and more effective product development as the key to long-term competitive advantage.

Several previous DoD efforts to reduce development time have proven ineffective. In 1983, Dr. Jacques Gansler participated on the Air Force Affordable Acquisition Approach study, which examined 109 DoD programs to answer the question, “Does it really take longer and cost more to develop systems now or is it just perception?” The study group found that development time had indeed increased significantly since the 1950s and made a series of specific recommendations to reduce them. In 1986, the Packard Commission’s Acquisition Task Force, headed by Dr. William Perry, stated in its Formula for Action that excessively long acquisition cycles are “a central problem from which most other acquisition problems stem,”[1] concluding that it was “possible to cut this cycle in half.”[2] The Packard Commission then made its own series of recommendations. President Reagan directed DoD to implement the Packard Commission recommendations, and Congress legislated recommended organizational changes. Yet, since 1986, the development time for major defense systems has continued to grow: major new systems fielded during the 1990s have required an average of 11 years from the decision to proceed to initial operational capability. The time from decision to proceed to delivery of the first production item accounts for 112 of the average 132 months.

Despite continuing growth in development times, recent acquisition reform efforts have focused almost solely on reducing costs. While conducting this research, the author has encountered many people within DoD and the military services who do not believe that reducing development time is important. One senior DoD acquisition reform leader stated bluntly that she was not interested in such an effort unless it would cut costs. Survey results obtained as part of this research confirm the low priority placed on reducing development time by the acquisition community.

The objective of this research is to improve the DoD acquisition process to allow better equipment to reach warfighters more quickly and at lower cost. Cutting development times is also key to developing systems that respond effectively to changing military needs and take advantage of new technologies. An overall shift in strategy away from developing a wide array of systems to counter all potential threats toward one more responsive to specific threats will ensure that the right weapons are ready when they are needed.

[1] President’s Blue Ribbon Commission on Defense Management. “A Formula for Action: A Report to the President on Defense Acquisition” (The Packard Commission Report) Washington D.C. April 1986. Pg. 8.

Cutting development cycles will also extend the time that forces maintain their technical advantage. If a system is quickly compromised by countermeasures, its long-term worth is questionable. Thus the U.S. Air Force now builds systems "just-in-case" as insurance against a "pop up" threat. That is one argument for the F-22 and the Joint Strike Fighter, both of which are intended to counter threats that may develop over the next 30 years. Indeed, while 70% of the projects surveyed were designed to meet current operational deficiencies, fully 30% were intended to meet projected needs.

The net effect of such a strategy is that some systems are often developed to counter threats that never materialize. What's more, when systems are finally fielded they often must perform a dramatically different mission than they were designed for. This produces the worst type of inefficiency: developing and producing the wrong weapon at the wrong time with obsolete technology, or one that does not meet the current need when fielded. The B-2, designed as a long-range nuclear bomber, and the MILSTAR, conceived as a strategic communication system for the second stage of a nuclear exchange, are visible examples of systems designed to meet missions that never materialized or disappeared before they were completed. The MILSTAR has been used instead as a tactical terminal, something for which its low data rate makes it ill suited in today's digital environment and large demand for information. The "just-in-case" strategy also forces the US to spread its resources over many systems, resulting in even longer development times.

To change the basic development philosophy to a "just-in-time" strategy, where systems are fielded as they are needed to maintain technological superiority, the US needs to be able to both develop and field a sufficient number of units quickly. Today the US takes 10 to 20 years to develop and field major new weapon systems, which are expected to be in operation for 20 to 25 years. That approach forces the US to project threats 40 years into the future -- a nearly impossible feat. The requirements that the F-22 and other planes retain technological superiority in the year 2020 and beyond is what pushes their demanding technology performance requirements and drives much of the cost of military systems. In general, the recent response to long cycle times has been to establish a long-term planning organization in the Pentagon to project the required force structure, the weapons, and the technologies required a full 25 to 40 years in advance. This may not be that bad except that the effect of these plans is to lock in the planned future systems and related schedules long before it is possible to know the actual threat. Once made, these plans and schedules prove very difficult and costly to change. The system is most closely comparable to the central planning function of the former Communist systems with little free market or

[2] President's Blue Ribbon Commission on Defense Management. "A Formula for Action: A Report to the President on Defense Acquisition" (The Packard Commission Report) Washington D.C. April 1986. Pg. 15.

entrepreneurial forces at work. Bureaucratic processes dominate the planning processes and one result of this process, as shown by the research, is long development times.

One effect of long development times for weapon systems is a large number of projects in development at once. This is the same problem found in many commercial firms that are experiencing product development problems. Too many products and too few resources to execute them effectively and efficiently result in long development times, significant schedule slips, and cost overruns. As will be shown, that is exactly what is happening in Air Force development efforts. It also forces large technology step sizes to ensure that the products are technologically superior when they are eventually fielded, which only exacerbates the problem.

As an alternative to the “just-in-case” strategy, one could go to a “just-in-time” strategy, where systems would be quickly developed to counter actual identified emerging threats. Resources could be more effectively targeted to counter the real threats instead of being spread over many systems to counter many potential emerging threats. This could allow for a more targeted approach in deciding which systems are needed and should be developed.

Having an effective and quick development process would allow a rapid response to a “pop up” threat that may be based on a new technology which would limit the duration and depth of any military exposure. Without an efficient and responsive development process, the US is vulnerable to unpredicted emerging systems based on new technologies or novel combinations of existing technologies.

A historical point is that this “just-in-time” approach is not new. It has been the traditional US military strategy from the Revolution through the Second World War. Only during the Cold War did we feel the need to have long-term technological superiority over all enemies. During WWII, the US developed better systems quickly and produced them massively. The speed and potential effects of the nuclear war and our lack of preparation for the Korean War made the US fear being caught unprepared. This developed into the idea of the “come as you are” war which would be fought in Europe and the ultimate winner would be determined in a matter of weeks before any production could affect the outcome. The fear of this type of total lightning war has been eliminated by the changes in Russia and the lessening of the perceived nuclear threat. Smaller operations will still be on a “come as you are” basis requiring significant, but not massive, inventories of the highest-technology weapons.

This fast development strategy may rely on a pre-developed set of critical technologies and subsystem components that are developed to the point where they can be assembled quickly, tested, and then produced as needed en masse. Such key technologies would be in the areas of sensors, signal and computer processors, communication systems, warheads, autonomous control, and navigation. The "develop and test but not produce" strategy would keep the US aerospace industry's product development capability in shape to ensure that it could be called upon when needed. It would facilitate multiple iteration of the designs, allowing for continual improvements without the cost of modifications. This strategy is similar to the design, build, test policies or the "Silver Bullet" ideas that surfaced during the early 1990's. Those were proposed more because of a lack of production money rather than a shift in the overall military development strategy to "just-in-time." The "Silver Bullet" strategy was not widely accepted for a variety of political reasons which may have changed since the end of the Cold War and the acceptance of decreasing defense budgets.

Another key aspect of this strategy would be to have a large reserve of production capacity that would be available in time of an emergency or an emerging threat. The central and enabling aspect of this would be reliance on the US commercial production capacity as a sort of "Civil Reserve Industrial Capacity," much as the Air Force relies on the Civil Reserve Air Fleet to augment its transport aircraft with airline aircraft. This requires that the military and commercial production capacities be merged. The merger of the defense and commercial production capacity is the major goal of efforts by the previous Defense Acquisition Executive, Dr. Kaminski, to remove military specification and standards and to go to single commercial standards and processes.[3] Dr Gansler, the current Defense Acquisition Executive, wrote of similar objectives and specified specific steps to begin to achieve civil-military integration in his book *Affording Defense*[4] and more recently in a June 3, 1998, letter to the Service Secretaries on the Single Process Initiative.[5] Integration of the defense and commercial industries allows the US to maintain the defense capacity for times of emergency without the cost of constantly producing defense products that we do not need at the present time. This also allows us to get away from the "defense industrial complex" requiring constant feeding and production to sustain itself as they would have commercial products that they can produce to maintain their capacity. The DoD would pay them to maintain military-specific equipment and capacities and maintain the ability to rapidly shift to produce needed military systems. Before that can happen, the defense industry must either become lean to compete in the commercial market, or the commercial companies must be allowed to compete in the defense market without large barriers. If one reads many of the Defense Science Board studies that were

---

[3] Perry, William. "Secretary of Defense Memorandum: Common Systems/ISO-9000/Expedited Block Changes." Dec 6, 1995.

[4] Gansler, Jacques. Affording Defense. Cambridge MA: MIT Press, 1989. Pg. 239, 279-282.

[5] Gansler, Jacques. "USD(A&T) Memorandum: The Single Process Initiative - A Long Term Perspective." 3 June 1998.

led by Dr. Perry and Dr. Kaminski as far back as the 1970's, the emphasis on the merging of the defense and commercial industry is a central theme and for this very reason.[6] This merging of production lines is starting to occur in the satellite, electronics, and engine industries, but to date it has not occurred in the aircraft or munitions areas.

There are both political and technology reasons that make the change from "just-in-case" to "just-in-time" strategy not only desirable, but also possible in today's environment where it may not have been possible 10 years ago. The technology-based reasons are: the key technologies for military systems are now primarily drawn from commercial technology developments; the rapid pace of commercial technologies has overtaken the military development effort; the development of open system architectures from commercial computer systems is making its way into military systems (Open Systems Initiative); the quality of commercial products often exceeds the military standard equivalents; and the acceptance of field-replaceable instead of field-repairable components allows the maintenance concerns to be reduced. Some of the political changes that may allow for this type of change to occur now are: the reduction of the military threat and a period of clear military superiority (we can take this time to reorganize without exposing ourselves to risk); the acceptance of substantially lower long-term defense budgets; the diminished threat of a global war and instead, a focus on regional conflicts; and a recognition on the part of industry and military leaders that things can and must change if we are to provide effective weapons for our forces over a long period.

The key to making such a change in development strategy is the reduction in the time it takes to develop and produce military-related products. The demonstrated capability to quickly develop and produce weapons is the key capability that will enable such a change to occur. Not only is reducing the product development time a key to improving the product development process, but it is also key to changing the strategy used to decide which systems to develop and how to equip our forces.

This research and its recommendations are intended to identify and eliminate the causes of long development times for military systems. It addresses what will be shown to be a key factor in determining the development time for military projects, the development of the project's initial schedule. This report is organized around the process used to carry out the study. Part 1 outlines the current situation, the previous efforts, and the commercial experience associated with

---

[6] Department of Defense. "Report of the Defense Science Board: 1986 Summer Study on Use of Commercial Components in Military Equipment." Office of the Under Secretary of Defense for Acquisition. Washington D.C. January 1987.

development time. It also documents the product development process. Chapter 1 identifies the current development time for military systems and found that they have consistently increased since the 1970s. It identifies some of the impacts of development time on military capability, cost, and the DoD acquisition system. Chapter 1 also identified the previous significant efforts to shorten development times such as the Packard Commission and other more contemporary efforts. Chapter 2 looks at the commercial successes at improving product development capability by focusing on development time. It provides experiences from the automobile industry and aerospace industries more closely related to the defense industry. Chapter 3 provides a description of the Air Force product development process as a representative example of how the DoD accomplishes its product development activities.

Part 2 of this report identifies a key research area, *the schedule development process, and its impact on development time*, for in-depth research. Through understanding what is driving the initial project schedule and the impact of the initial project schedule on the eventual development time, the author hopes to identify the key drivers of development time. Chapter 4 identifies the specific area of research and provides the framework for the research. Chapter 4 also reviews the previous research associated with project schedules associated with military projects. Chapter 5 describes the research method selected and used to collect the required data. It describes the reasons a survey-based method was selected and the factors that were considered in developing the three surveys used to collect project-level data at the Program Offices, the Pentagon, and the contractors. Chapter 6 presents the demographics of the 317 survey respondents to show that it is a representative sample of the current development efforts, both large and small. Chapter 7 describes the methods used to analyze and illustrate the results of the surveys.

Part 3 presents the results of the three surveys and the analysis of the processes used to develop a project's schedule and its impact on actual development time. Based on the survey results, Chapter 8 identifies the factors involved in developing a project's initial schedule. It analyzes users' schedule desires, the project objectives, and the influences on schedule. It identifies the schedule information and tools used, and the organizations involved in the development of a project's initial schedule. Chapter 9 shows the impact of the project's initial schedule on the project's contracted schedule. It shows what is driving the length of the contractor's proposed schedules and the results of these schedules. Chapter 10 identifies the incentives associated with the length of project schedules for the development of a project. It describes both the organizational and personal incentives at the Pentagon, program offices, and Contractor associated with project schedules. Chapter 11 then documents the achieved schedules and compares them to both the initial project schedules and estimates of the project managers of the minimum required time to develop the projects. It shows the impact on the overall development time that the project's initial schedule and the various factors that cause delays in projects have on the time it eventually takes to develop the project.

Based on the survey results, Part 4 draws conclusions, presents observations, and makes specific recommendations for remedial action. Chapter 12 draws specific conclusions on the schedule development process and its impact. Chapter 13 places these conclusions in the larger context and makes specific observations about the entire product development process. Chapter 14 makes specific recommendations for action that must be taken to improve the product development process and in particular the process used to develop the initial schedules of a development project. Chapter 14 then revisits the larger changes in development strategies enabled by the reduction in development times and how shorter development times may allow for a change from a "just-in-case" development strategy to "just-in-time" approach.

The ultimate objective of this research is to reduce development time in order to meet the ever-changing needs of our warfighters. Reducing development time is the key to improving the development process to allow it to provide higher-quality products, more rapidly, and at lower cost. Current long development times for military systems have significant negative impacts. Many commercial firms have achieved dramatic improvements in their product development processes by focusing on reducing development time. This research provides a detailed description of the complex processes the military uses to select, plan, and carry out development projects and the impact those processes have on the time it takes to develop and field these projects.

This research identifies key barriers to reducing development time and makes specific recommendations on how to remove them. The key barriers to reducing development time for military systems are the lack of importance placed on project schedules; the lack of effective schedule-based information and tools; the lack of schedule-based incentives; and the overriding impact of the funding-based limitations on defense projects. The steps necessary to establish a focus on reducing development time are: 1) recognizing the impact of development time, 2) providing the necessary information for decision makers, 3) providing proper incentives at each organizational level, and finally, 4) providing a structure to effectively manage the set of all development projects to ensure that each project can be funded based on its development-related requirements.

The implementation of the recommendations and a focus on reducing development time will force other necessary improvements in development and other acquisition processes. The focus on reducing the time to develop and field systems will drive the acquisition system to better meet the needs of our warfighters, more rapidly, and at lower cost. Better, Faster, and Cheaper. Even more importantly, shortening development times is critical to develop and produce, with limited resources, the right weapons at the right time to deter or to defeat any potential enemy at any time with the minimum cost to our warfighters. The recommendations of this effort should be implemented forthwith to begin the long and difficult process that is required to shorten the development times and increase the effectiveness of our military product development system.

Biography

Ross McNutt

Ross McNutt is a Major in the United States Air Force. He is receiving his Doctorate of Philosophy in Technology, Management, and Policy, an interdisciplinary program including aspects of engineering, management, and political science from the Massachusetts Institute of Technology. He received his Master of Science Degrees in Aeronautics and Astronautics and Technology and Policy Program in 1992 also from the Massachusetts Institute of Technology. He received his Bachelor of Science Degrees in Mathematics and Physics with academic distinction from the United States Air Force Academy in 1987. Major McNutt graduated high school Cum Laude from Culver Military Academy in Culver, Indiana.

Major McNutt is currently an Air Force Strategic Business Planner with the Secretary of the Air Force for Acquisition at the Pentagon in Washington D.C. Here he is developing, coordinating, and executing acquisition reform efforts for the Air Force and the Department of Defense based in part on this work. Previously Major McNutt was a research assistant with the Lean Aerospace Initiative at Massachusetts Institute of Technology from 1994 to 1998. He was a Satellite Engineer controlling the Global Positioning System satellites at Falcon AFB Colorado from 1992 to 1994. Major McNutt was a research physicist and squadron section commander at the Air Force Phillips Laboratory at Hanscom AFB Massachusetts from 1987 to 1992.

Major McNutt has received several honors. He was the Air Force Space Systems Division Officer of the Year in 1989, and Officer of the Quarter for the 2nd Space Operations Squadron, 50th Space Wing, Geophysics Laboratory, Air Force Space Technology Center.

Acknowledgments

There are many people to thank for all their support over the years. I owe a great debt of gratitude to a large number of people. To Kosta Tsipis, who has been a great mentor, advisor, and friend. Thank you for your confidence and trust in me both to push me and let me discover new paths and then to follow them. Kosta, you have taught me many valuable lessons; the most important that I have learned through observation is that one person can make a difference. That through actions, grounded with reasons, one can change the way things are and make the world a better place.

I owe a great debt of gratitude to the Lean Aerospace Initiative. The Lean Aerospace Initiative is an outstanding group of dedicated, intelligent, smart and fun people who are making a difference. Earll Murman and John Deyst, thank you for both allowing me the time to follow avenues that at times looked dark and uncertain. Your time, patience, advice, and support were critical to the success of this effort. The assistance and insight, as well as the lessons I have learned and am applying, go well beyond the academic and will assist me in all that I do. Thank you for establishing the Technology and Policy Program. Eric Rebentisch, your assistance in the surveys and through many long discussions helped me immensely. Thank all of you for your patience and assistance throughout this effort. To the many students, staff, and participants who supported, shared ideas, and helped make the time one of the most rewarding periods through learning, sharing, friendship, and camaraderie. Each of you will be immensely successful in your futures. Good things come to good people.

I also owe a great deal to the wonderful people in the Technology and Policy Program. Richard de Neufville has established the absolute best program of its kind in creating engineers making a difference. Thank you Richard for your efforts assisting me personally and your long term guidance and support of both the program.

I owe much to the Air Force (in addition to the next 10 years) for allowing me to return to MIT and providing me the time, the support, and the assistance throughout the research. Thank you for allowing me the opportunity to learn and also to assist in making this a better Air Force by allowing me to contribute to the best of my ability.

To my wife, Stacy, who through all the struggles, frustrations, and periods of doubt, managed to keet faith in me, to always be there for me, to always support me in whatever ways necessary. Without you, your support, your sacrifice, your patience, and your understanding, I would be lost. Thank you for always being there, supporting and encouraging me as you always do. Thank you for having Catherine and JoAnna just after, and not before the general exams. Thank you for allowing me to take this opportunity and to follow through on my hopes and dreams. Andy, my young but quickly growing son, thank you for being such a great kid, for keeping my priorities straight, and being so understanding when Dad had to use your computer. Catherine and JoAnna, thank you for being such wonderful little girls and help me keep perspective on what is truly important.

Reducing Air Force Product Development Time: The Role of the Schedule Development Process

Table of Contents

PART 1

PROBLEM IDENTIFICATION AND DEVELOPMENT PROCESS OVERVIEW

PART 2

RESEARCH INTO THE PROCESS USED TO DEVELOP PROJECT SCHEDULES

PART 3

THE DEVELOPMENT OF A PROJECT'S INITIAL SCHEDULE AND ITS IMPACTS: SURVEY RESULTS AND ANALYSIS

PART 4

CONCLUSIONS, OBSERVATIONS, AND RECOMMENDATIONS

APPENDICES

Part 1

Problem Identification and Development Process Overview

Part 1: Overview

Part 1 of this thesis, consisting of Chapters 1 through 3, describes some current issues associated with the Air Force product development process and the problem of long development cycles. Chapter 1 identifies the nature of the problems that lead to long cycle times and discusses past and current efforts to address them. Chapter 2 describes significant advances in the commercial sector that have resulted from applying lean development practices. Chapter 3 specifically describes Air Force product development processes to establish a frame of reference for discussions in later chapters.

Chapter 1

Long Development Times for Military Systems

The U.S. Department of Defense oversees the world's largest product development operation. Over the past 20 years, DoD has spent the 1998 equivalent of $732.5 billion on researching, developing, testing, and evaluating new systems. In 1997 alone it spent $32.5 billion developing new or improved military systems, despite a 30 percent drop in annual development dollars since 1989.

Today, development-related activities represent 42 percent of DoD's total procurement costs. This amount does not include the tens of thousands of military and civilian DoD employees assigned to acquisition-related positions, nor the development-related activities associated with operating and maintaining existing systems. Based on analysis of the defense budget over time, the money going to research and development (R&D) on new weapon systems represents an increasing fraction of all modernization dollars, and this fraction is currently at an all-time high. For many programs, development costs significantly exceed procurement costs. Development costs combined with the rapid rate of technological advances—plus the impact on operational capabilities and costs—make the DoD development process a central issue in defense acquisition.

Many efforts have been made to improve the military acquisition system over the last several decades. The most influential reform initiative was the Presidential Blue Ribbon Commission led by David Packard in 1986. The Packard Commission identified long development time as the key problem and stated in its conclusion:

> Serious result of this management environment is an unreasonably long acquisition cycle--ten to fifteen years for our major weapon systems. This is a central problem from which most other acquisition problems stem: . . . it leads to unnecessarily high costs of development, . . . obsolete technology . . . and aggravates the very gold plating that is one of its causes.
>
> Packard Commission Report[7]

As it introduced its recommendations, the Packard Commission stated:

> Acquisition problems have been with us for several decades, and are becoming more intractable with the growing adversarial relationship between government and the defense industry, and the increasing tendency of Congress to legislate management solutions. In frustration, many have come to accept the ten-to-fifteen years acquisition cycle as normal, or even inevitable.
>
> We believe that it is possible to cut this cycle in half.
>
> Packard Commission Report[8]

Long product development cycles have a serious impact not only on the military's acquisition system but also on its warfighting capabilities. DoD leaders have long complained that it takes too long to develop and field new systems and too long to meet the needs of warfighters. In 1986, the Packard Commission reported:

> "The Chairman of the Joint Chiefs of Staff stated that the most important way technology could enhance our military capability would be to cut the acquisition cycle in half."[9]

More recently, Secretary of Defense William Cohen in March of 1997 stated:

> . . . we need fast-paced acquisition systems that can seize upon the new technologies. . . . We need to quickly put this technology into the warfighters' hands to meet their needs while . . . it is still new and very competitive. [10]

General Ronald R. Fogleman, former U.S. Air Force Chief of Staff, indicated the importance of making the acquisition system more responsive to warfighters' needs:

---

[7] President's Blue Ribbon Commission on Defense Management (Packard Commission). "Formula for Action: A Report to the President on Defense Acquisition." 1986. Pg. 8.

[8] Packard Commission. "Formula for Action: A Report to the President on Defense Acquisition." 1986. Pg. 15.

[9] Packard Commission. "Formula for Action: A Report to the President on Defense Acquisition." 1986. Pg. 35.

[10] Cohen, William and Kaminski, Paul. "DoD Press Conference." 14 March 1997. Reported in Program Manager. Defense Systems Management College. May June 1997. Pg. 15-18.

> It's essential that we make our acquisition system more responsive to the needs of the warfighter. We've engaged our partners in industry to help us improve our acquisition process and produce more combat capability for the dollars we invest. . . . Working together, we can provide a truly responsive acquisition process that fields the capabilities required to underwrite asymmetric force application in a timely and cost-effective manner.[11]

The Honorable Paul Kaminski, Under Secretary of Defense for Acquisition and Technology, put it more straightforwardly when he told a Senate Committee:

> The Department of Defense cannot afford a 15-year acquisition cycle time when the comparable commercial turnover is every 3 to 4 years. The issue is not only cost. The lives of our soldiers, sailors, marines, and airmen may depend upon shortened acquisition cycle times as well. In a global market, everyone, including our potential adversaries, will gain increasing access to the same commercial technology base. The military advantage goes to the nation who has the best cycle time to capture technologies that are commercially available; incorporate them in weapon systems; and get them fielded first.[12]

---

[11] Fogleman, Gen. Ronald R., U.S. Air Force Chief of Staff. "Air Power and the American Way of War." Presented at the Air Force Association Air Warfare Symposium. Orlando, Florida. Feb 15, 1996.

[12] Kaminski, Paul G. "Statement of the Under Secretary of Defense for Acquisition and Technology, Paul Kaminski, before the Subcommittee on Defense Technology, Acquisition and Industrial Base of the Senate Committee on Armed Services on Dual Use Technology." May 17, 1995.

A. Acquisition Response Time

The acquisition cycle, to which the leaders refer, can also be described as the acquisition response time. Acquisition response time is the time from the emergence of a threat, an operational need, or a new technological opportunity to the delivery of enough systems to provide operational capability. Acquisition response time is thus a measure of the responsiveness of the entire acquisition system to meet the needs of warfighters. This time includes recognition time, decision time, development time, and production time.

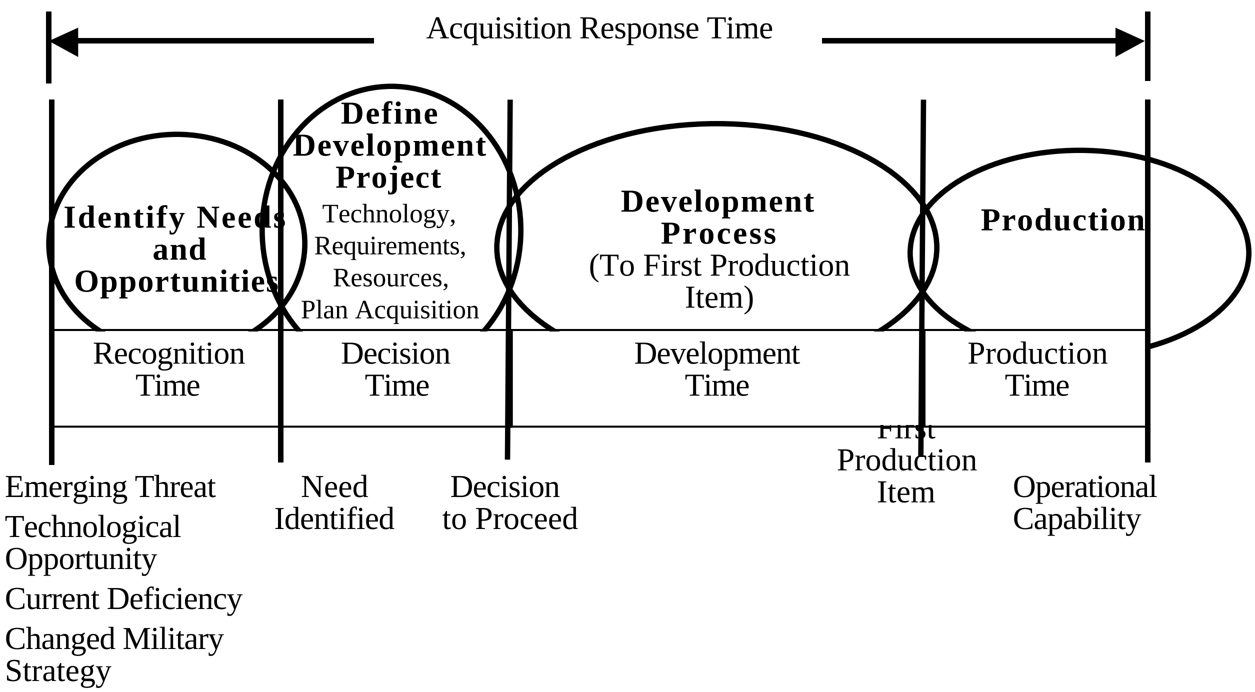


Figure 1-1: Components of Acquisition Response Time -- Time to Meet the Customer's or User's Needs.

Recognition time begins when a new threat emerges, a deficiency in the ability to execute a military strategy appears, a change in military strategy that requires new systems occurs, or a technological opportunity with significant military application emerges. Recognition time ends when the services formally recognize the need for a new system. This is typically done through a Mission Needs Statement.

Decision time begins when the need is recognized and ends when a decision is made to proceed with a development effort to fill that need. During this period leaders must decide which needs among many to address, and which opportunities to pursue. During this time, leaders also define the requirements for a new system, determine which technology to use, allocate the resources, and create a development plan. Decision time ends with a Milestone I decision or project approval.

Development time begins with the decision to start the project and ends with the delivery of the first production item. This stage includes selecting contractors, refining the product's design and the process used to make it, prototyping, testing, and producing the first representative system. By the end of this period, the vast majority of product and process development activities are complete. Further improvements to the production process can be attributed to the learning curve during production.

Production time begins with completion of the first item and ends when enough systems are produced and fielded to provide an effective operational capability. In the military,this is marked by the "required asset availability" (RAA) date, or by the declaration of "initial operational capability (IOC)". Not until this point do warfighters consider a system usable for the intended mission.

Determining overall acquisition response time is often difficult because it is unclear exactly when an opportunity opens or a threat emerges. Decisions can occur quickly if an opportunity or threat catches a leader's attention, but potential projects can also languish for years within the modernization planning process, never managing to make it above the cutoff line. Based on observation of many programs, decision makers may also take as long as five years to build the necessary consensus for starting a development project.

B. Development Times for Military Systems

Development time is easier to examine and analyze since it has a more defined beginning and end. Development time for all major defense acquisition programs[13] averaged 106 months, or nearly 9 years, from 1965 to 1995, as shown in Figure 1-2 below. Air Force the smaller sized ACAT II projects--those costing between $355 million and $140 million for development --

[13] Major Defense Acquisition Programs are those that have more than $355 million in projected development costs or more than $1 billion in projected production costs.

averaged 66 months. Smaller ACAT III projects--those costing less than $140 million for development--averaged 51 months. [14]

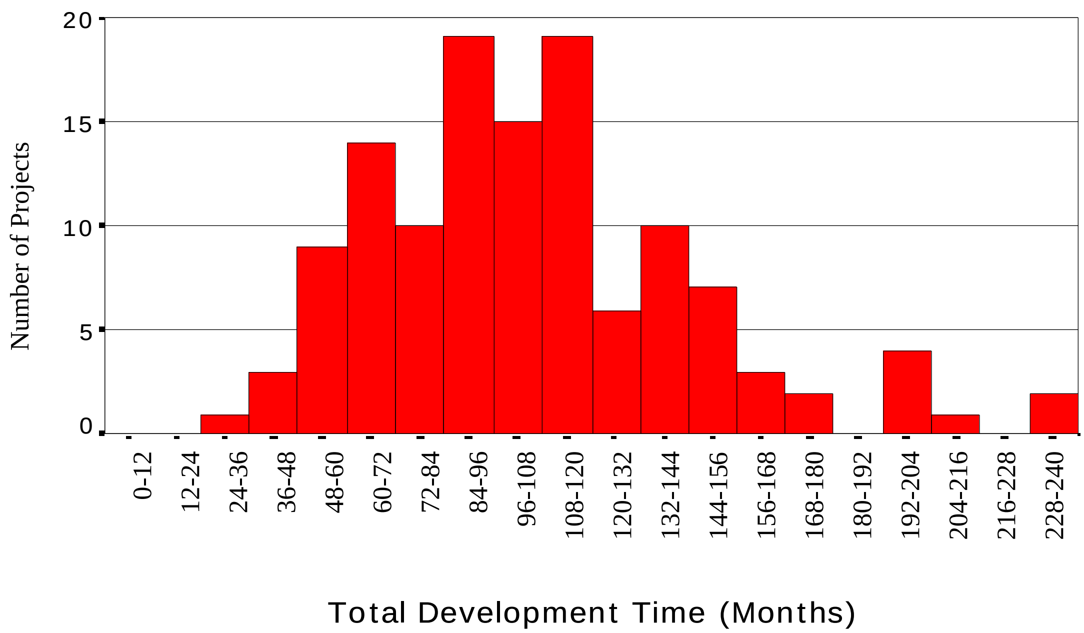


Figure 1-2: Distribution of Product Development Time for Major Defense Acquisition Systems Since 1965.[15]

[14] ACAT refers to the Acquisition Category of the program which is determined by the potential cost of the project in development and production. The ACAT size often determines the reporting requirements of the project.

[15] J.M. Jarvaise, J.A. Drezner, and D.M. Norton. "The Defense System Cost Performance Database: Cost Growth Analysis Using Selected Acquisition Reports." Santa Monica CA: RAND. MR-625-OSD Data current as of December 1994.

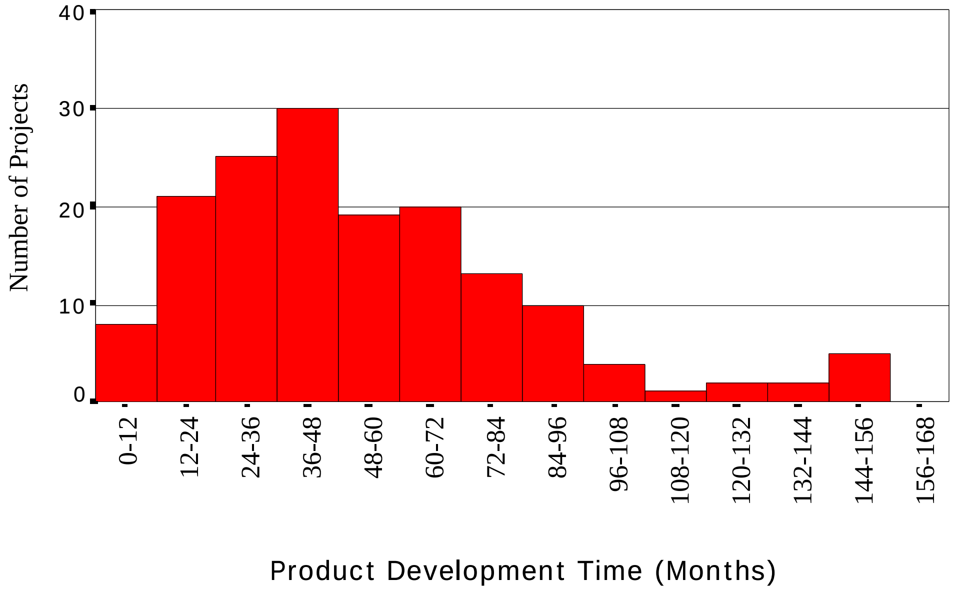


Figure 1-3: Distribution of Development Time for Smaller Air Force Development Projects (Current ACAT II and ACAT III Projects).[16]

Development times have increased since the Packard Commission report was issued in 1986. Development time for major defense projects, based on the date of the first delivered operational item, has grown from 97 months in the first half of the 1980s to 108 months in the first half of the 1990s. Development time appears to be headed for 115 months for the second half of 1990's, and to over 120 months--more than 10 years--after 2000, as shown in Figure 1-4. (No projected data are available for smaller projects.)

The figure shows the times from program start (Milestone 1) to first operational delivery. The figure does not include pre-Milestone I activities, which can last up to 5 years, nor does it include time from first operational delivery through delivery of enough quantities for operational use.

As shown in Figure 1-5, long product development times occur across all types of systems. Of particular note is that electronic systems, munitions systems, and helicopters average more than 10 years in development.

---

[16] Data provided by Secretary of the Air Force (Acquisition) SAF/AQXR. Definitions of start and stop points used to determine development time could not be verified.

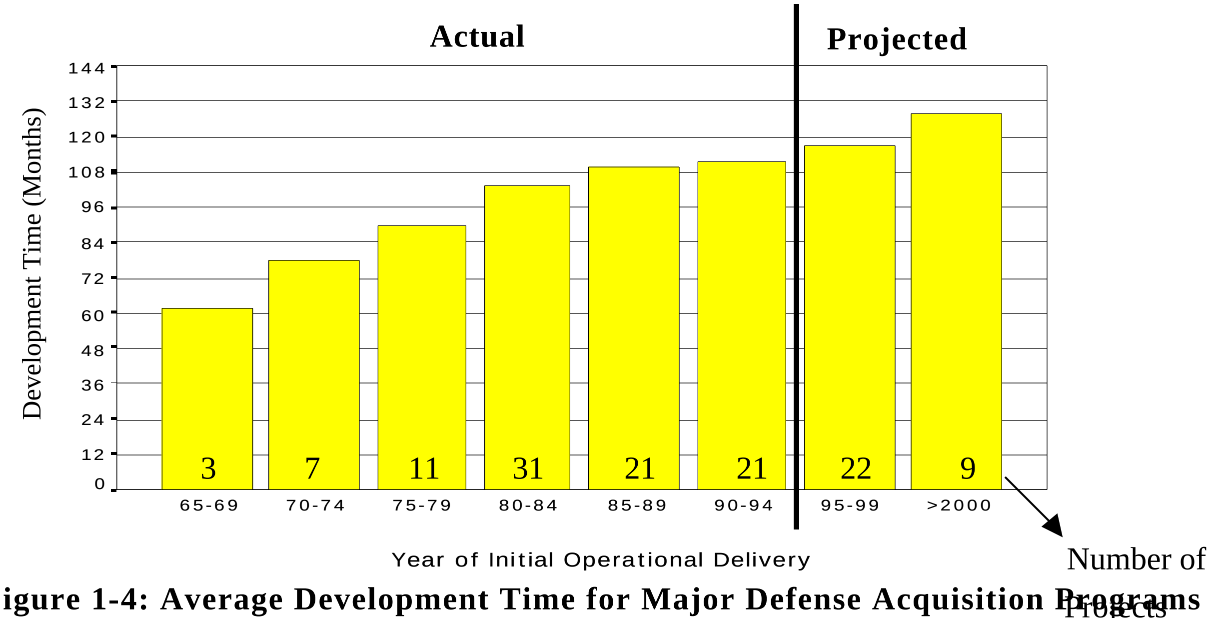


Figure 1-4: Average Development Time for Major Defense Acquisition Programs by Year, (Measured from Program Initiation (Milestone 1) to First Operational Delivery).[17]

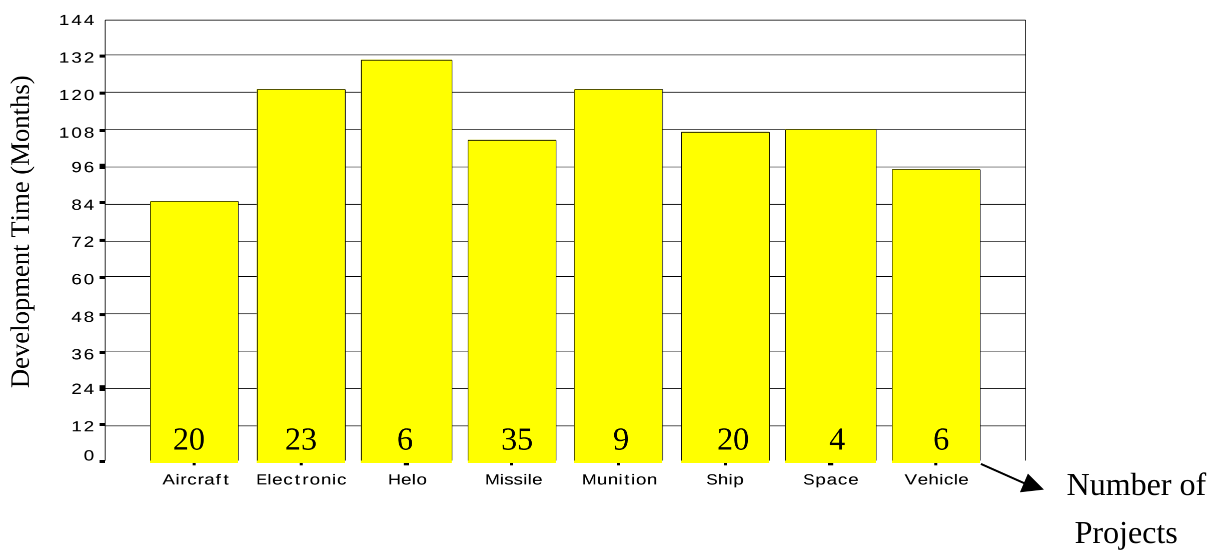


Figure 1-5: Average Time from Program Initiation to First Operational Delivery for Major Defense Acquisition Systems.[18]

[17] Data from Rand SAR Database. J.M. Jarvaise, J.A. Drezner, and D.M. Norton. "The Defense System Cost Performance Database: Cost Growth Analysis Using Selected Acquisition Reports." Santa Monica CA: RAND. MR-625-OSD Data Current as of December 1994. Averaged over all major defense acquisition programs with available data. Note the 70-74 data may not contain some long running program data that was not included in the SAR database as some programs preceded the SAR reporting requirements.

Little solace can be taken from the relative speed of the process for developing military aircraft, such as the F-16, KC-10, and A-10. More contemporary efforts, such as the C-17 (150 months), F-22 (144 months), and T-45 (111 months), average significantly longer development times.

Average development times for smaller Air Force ACAT II and ACAT III projects (below $355 million in development costs) are shown in Figure 1-6 below.

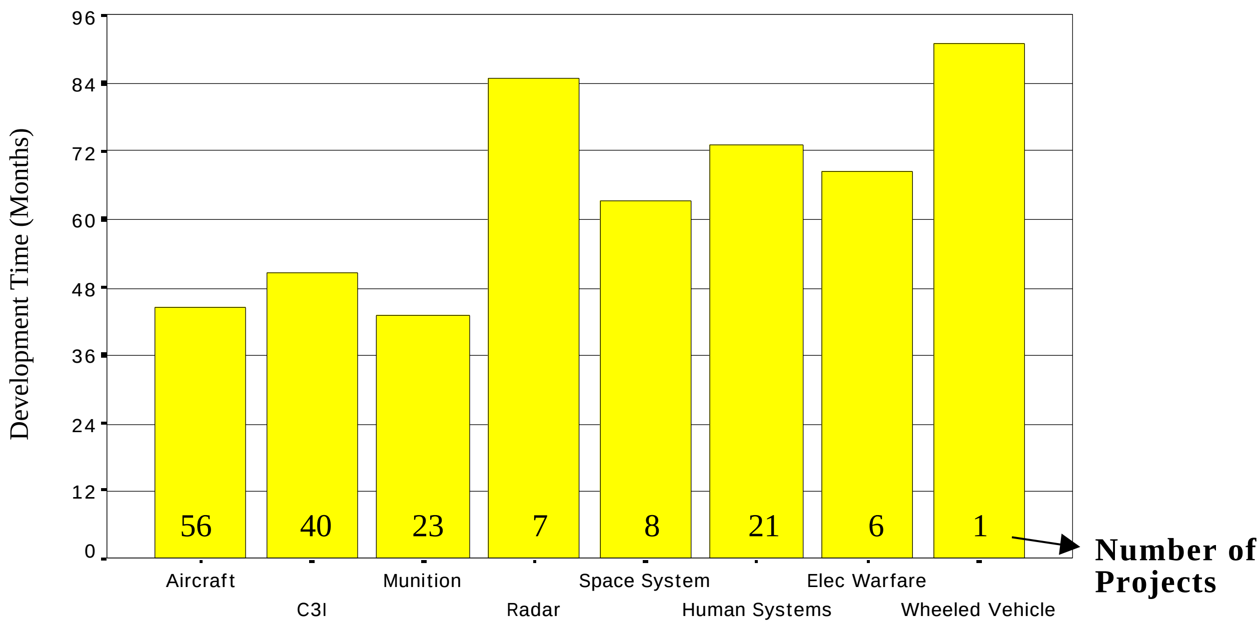


Figure 1-6: Projected Average Development Times for Current Smaller Programs (ACAT II and ACAT III Projects) [19]

[18] Data from J.M. Jarvaise, J.A. Drezner, and D.M. Norton. The Defense System Cost Performance Database: Cost Growth Analysis Using Selected Acquisition Reports." MR-625-OSD. Santa Monica CA: RAND. Data current as of December 1994.

[19] Projected development time provided by the Assistant Secretary of the Air Force for Acquisition (SAF/AQXR). Definition of start and stop points used to determine development time could not be verified. Percent of development complete also could not be determined.

For new programs completed in the 1990's, the average time from program start to initial operational capability—the real test—is over 10 years. This average is available from a recently developed database from the Office of the Secretary of Defense. This database is based on Selected Acquisition Reports and is current as of March 1998.[20]

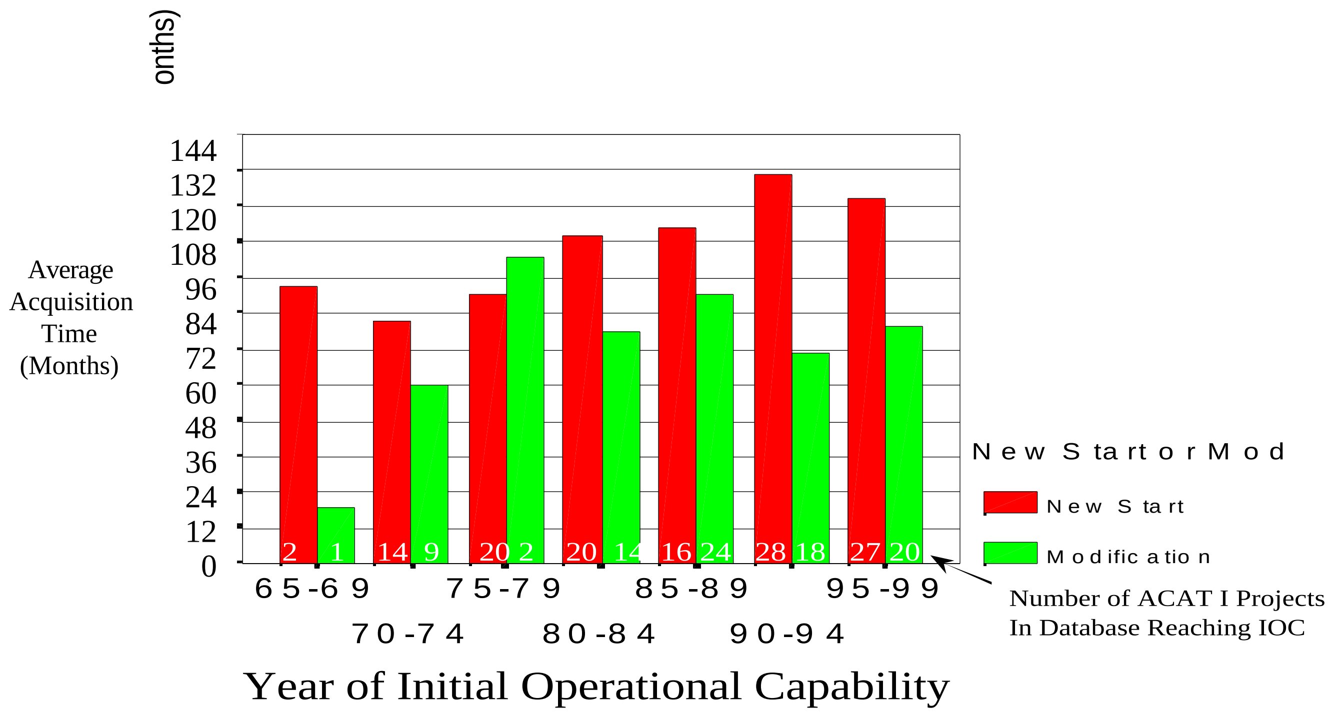


Figure 1-7: Time from Program Initiation to Initial Operational Capability for Major Defense Acquisition Programs, from OSD(A&T) API ACTS database of 215 Major Defense Acquisition Programs.

The scenario feared by the Packard Commission—that the military would come to accept 10 to15-year acquisition cycles—has apparently occurred Systems now in initial stages have been planned with long development cycles. The newest system, the Joint Strike Fighter, which has just begun its demonstration phase, is scheduled to be operational in 2008 after 12 years of development. The AIM-9X off-boresight missile used in close air-to-air combat is expected to reach initial operational capability in 2003 -- nine years after program initiation despite the fact that a prototype was demonstrated as early as 1994, and despite the fact that the weapon fulfills a

[20] Department of Defense OSD(A&T) API. DoD Cycle Time Analysis Tool. 15 January 1998.

strong identified need and that it has significant political backing.[21] Even the F/A-18 E/F, an upgrade of an existing fighter, is scheduled to take 11 years from initial contract award in1991 until initial operational capability in 2002.

The "nominal" or planned times for proceeding from program initiation to the beginning of production, shown in Table 1-1 and taken from a Defense Systems Management College chart, range from 6 to 13 years. When one includes the production process, the acquisition cycle takes 8 to 21 years—potentially one year longer than a successful military career.

Phase 0	Concept Exploration	0-2 years
Milestone 1	Program Initiation	
Phase I	Demonstration and Validation	2-4 years
Milestone 2		
Phase II	Engineering and Manufacturing Development	4-7 years
Milestone 3		
Phase III	Production and Deployment	2-8 years
Phase IV	Support	10-50 years
	Development Range	6-13 years
	Deployment Range	8-21 years

Table 1-1: "Nominal" or Planned Defense Acquisition Time Scales.[22]

Exacerbating long planned development cycles, only half of DoD development programs meet their schedule. Many programs are delayed for years, some because of technical problems, some for funding reasons, and some because of changing requirements. Electronic systems and munitions systems, for example, average 21 months' delay. Figure 1-8 below shows the number of major defense acquisition programs that experience schedule slips. Table 1-2 shows the planned and actual schedules for different types of major development projects.

System Type	Planned (months)	Achieved (months)	Average Slip (months)	Number of Programs in Database
All Programs in database	90	106	14	131
Aircraft	78	83	2	23
Ship	98	107	8	24

[21] M. Dornheim and D. Hughes "U.S. Intensifies Efforts to Meet Missile Threat." Aviation Week and Space Technology. October 16, 1995. Pg. 39 and June 6, 1994. Pg. 44.
[22] Defense Systems Management College Chart -- Defense Systems Acquisition Management Process. May 92 and 97.

Munitions	87	121	26	8
Missile	92	105	13	25
Space	97	109	8	6
Electronic	97	121	21	29
Vehicle	76	95	14	9
Helicopter	96	131	46	5
Other	58	68	11	2

Table 1-2: Months from Program Initiation to First Operational Delivery of Major Defense Acquisition Programs.[23]

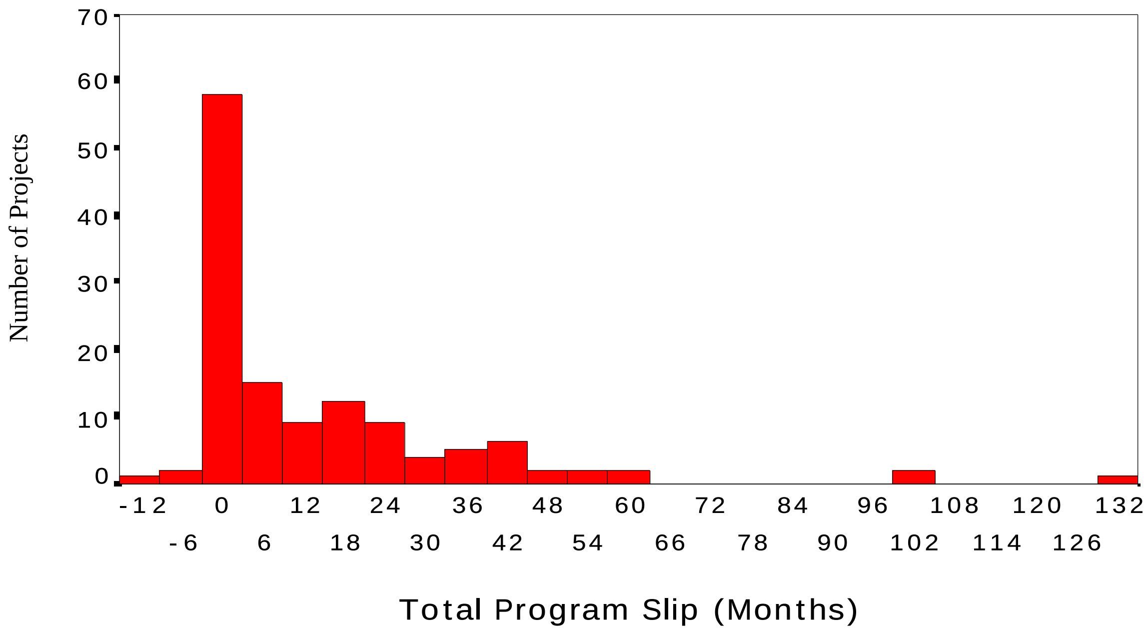


Figure 1-8: Distribution of Schedule Slip for 131 Major Defense Acquisition Programs (mean schedule slip: 13.8 months). [24]

[23] Data from J.M.. Jarvaise, J.A. Drezner, and D.M. Norton. "The Defense System Cost Performance Database: Cost Growth Analysis Using Selected Acquisition Reports." Santa Monica CA: RAND. MR-625-OSD. Data current as of December 1994.

[24] Data from J.M. Jarvaise, J.A. Drezner, and D.M. Norton. The Defense System Cost Performance Database: Cost Growth Analysis Using Selected Acquisition Reports." Santa Monica CA: RAND. MR-625-OSD. Data current as of December 1994.

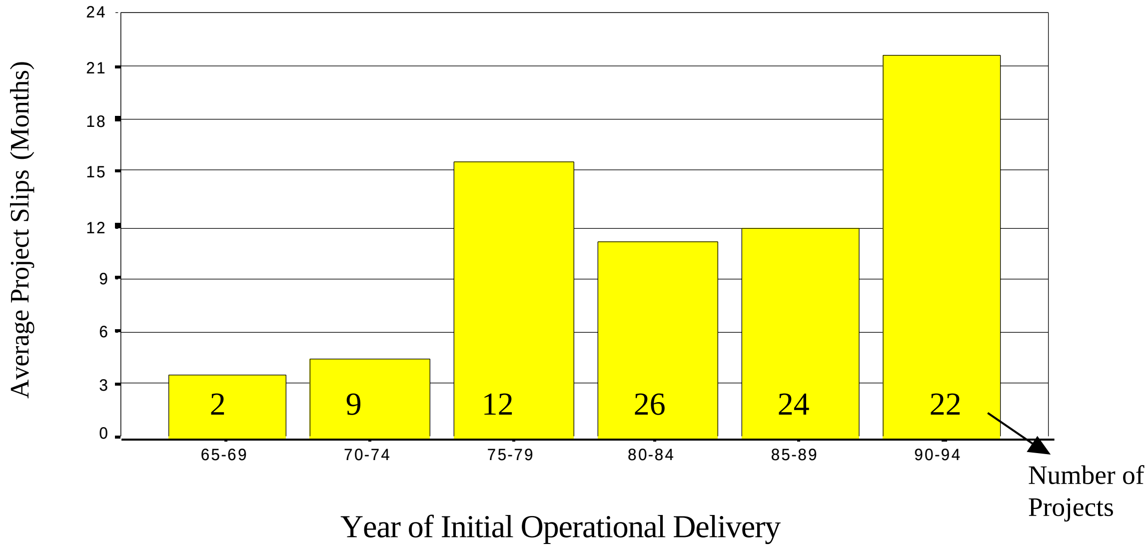


Figure 1-9: Average Project Slip by Date of Initial Operational Delivery for Major Defense Acquisition Program.

The data show that development time, including the slip in the schedule, averages over 106 months for major defense systems. Recognition time, decision time, and the time from first production item to delivery of enough systems for effective capability only add to these lengthy periods. The last of these, the time from decision to proceed to initial operating capability, was the primary focus of the Packard Commission which faulted the excessively long acquisition cycle, and of their recommendations for reforming the acquisition system.

C. Impact of Long Development Times

Long development times impact the DoD in many ways. They impact our military capability through systems, long in development, not being ready when needed. They impact our military capability through systems' not meeting the current need when fielded. They impact our military capability through fielding of dated technology in our newest systems. They impact our ability to quickly respond to new or emerging threats or to respond to known safety issues. Long development times also result in increased cost to develop and sustain our weapon systems. Examples of each type of impact of long development times are provided in Appendix 2.

C.1. Systems Not Ready When Needed

Desert Storm provided a unique opportunity to identify military needs in a wartime environment and determine the possible impact of equipment in the development pipeline had it been deployed more quickly. Seven systems that were long in development would have mitigated critical needs during the early part of Desert Shield and Desert Storm. These systems were the C-17 strategic and tactical heavylift cargo aircraft (started 1980), MILSTAR survivable satellite communications (started 1981), LANTIRN Precision Targeting System (started 1979), Joint Tactical Information Distribution System (started 1974), Global Positioning System (started 1973), Advanced Medium Range Air-to-Air Missile (started 1978), Sensor-Fuzed Weapon wide-area anti-tank capability (started 1983). Additional details are provided as to the program circumstances and impact in Appendix 2.

Many other major defense systems had been under development for at least five years were not available for use in Desert Shield or Desert Storm. Those included the Stingray Anti-Aircraft Missile, the V-22 Osprey, the AGM-130 Powered Glide Bomb, the Mark XV Identification Friend or Foe, the Army Brilliant Anti-Tank Weapon, the Advanced Apache Longbow and Hellfire Missile System, the Comanche attack helicopter, the AWACS Block 30-35 upgrade program, the F-22 air superiority fighter, and the B-2 strategic bomber. All these systems were started based on an identified need. Many of these systems have still not reached operational status 7 years later.

A few systems were rushed through development and made available to troops during the six months prior to Desert Storm. The JointSTARS surveillance plane was pushed into service and provided critical observations of Iraqi troop movements. A bomb system, the Bunker Buster, was developed and fielded in 29 days. This rapid action demonstrated that the acquisition system can move quickly to meet the needs of warfighters when they are seen as essential. But such efforts are the exception rather than the rule.

C.2. Systems Not Meeting Current Needs When Fielded

With the average development time for a new major defense system approaching 10 years, the need for and requirements of any system in development may dramatically change. Many of the systems now in the pipeline are based on the threat and political environment that existed before the dissolution of the Soviet Union and the Gulf War. Of 26 current major development programs in the Rand database due for completion between 1995 and 1999, only 6 were started following the end of the Cold War. Twelve began during the early 1980s, when the US faced a radically different environment. One result is that systems often do not adequately meet warfighters’ current needs when fielded.

C.3. New Systems Fielded with Dated Technology

In the time now required to develop and field a new military system, technology is no longer state of the art, and in some cases it is obsolete and out of production. Thirteen years ago, the Packard Commission stated that long development cycles "lead to obsolete technology in our fielded equipment. We forfeit our five-year technological lead by the time it takes us to get our systems from the laboratory into the field."[25] This problem is severely exacerbated by the rapid rate of advance in electronics. Technologies are usually selected and "frozen" early in full-scale development, significantly undermining programs based on fast-moving electronic and computing technologies. These effects can be seen in programs such as the F-22, Joint STARS, and AWACS Radar System Improvement Programs (RSIP), all of which are heavily dependent on computer processing. Current processors available operate significantly faster. As a point of reference of today's technology used in home computers, the current Pentium II processor, operating at 300MHz, can execute the equivalent of 627 million instructions per second (MIPS).[26] Current processor speeds available on these systems range from 8 to 56 MIPS. The specific program details are contained in Appendix 2.

[25] President's Blue Ribbon Commission on Defense Management. "A Formula for Action: A Report to the President on Defense Acquisition" (The Packard Commission Report) Washington D.C. April 1986.

[26] Based on analysis of processor performance from Intel Corporation processor facts sheets from their web pages.

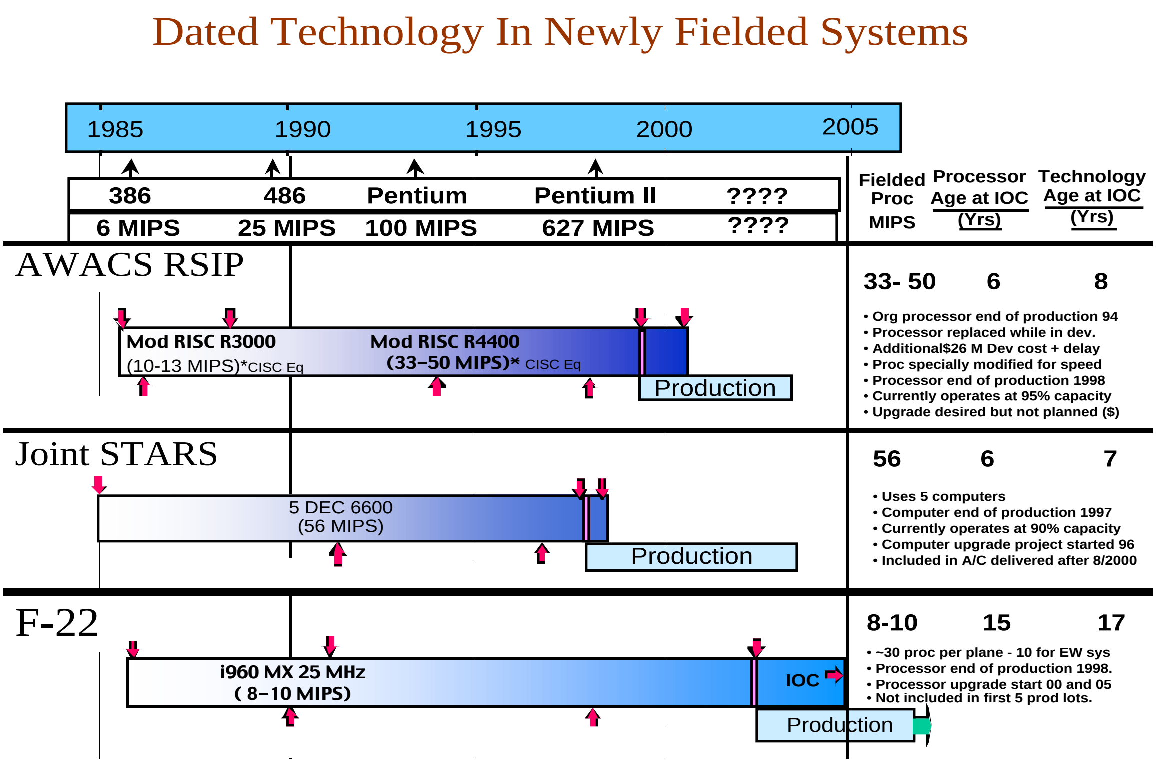


Figure 1-10: The Progression of Commercial Computer Processors vs. Processors Fielded in AWACS RSIP, Joint STARS and F-22 Aircraft .[27]

Computer processors are not the only area of technology that is rapidly changing. Other areas include digital signal processors, memory, sensors, communication systems, autonomous control, and navigation technologies. The rapid advances within the commercial electronics area are driving many of these technology advances. Military aircraft, ships, and space systems rely heavily on such electronic systems to provide communication and control.

C.4. Slow Response to New or Emerging Threats

Emerging threats based on new technology or a unique combination of existing technologies can pose a significant challenge to U.S. forces, and leave them exposed. Closing the performance gap and quickly developing counter-systems is an important aspect of maintaining technologically superiority.

---

[27] Source: F-22, AWACS, and JointSTARS Program Offices.

One example of the US failure to pursue this strategy has been the development of the Aim-9X—the US counter-system to the Soviet Archer AA-11 off-boresight air-to-air missile that the Soviets deployed in 1985. Off-boresight missiles can attack aircraft at a wider angle then standard air-to-air missiles, allowing aircraft equipped with them to fire on opponents at greater angles from the nose of the aircraft and significantly increasing their chances of killing the opponent before being shot down. The Israeli's developed and fielded a similar missile, the Python, in 1993. The AIM-9X is expected to reach operational capability in 2002 -- 17 years after the threat was identified. Currently, no U.S. fighter has any off-boresight missile capability.

C.5. Slow Response to Known Safety Problems

The current development process is also often slow to respond to identified safety requirements. Two high-visibility programs that exemplified this slow response are the integration of Traffic Collision and Avoidance Systems and Global Positioning System receivers on military aircraft. The long time to field these systems contributed to a number of avoidable aircraft accidents. The lack of GPS equipment contributed to the crash of a T-43 (Boeing 737) in Bosnia carrying U.S. business leaders on a trade mission and the crash of a C-130 Presidential support plane. The lack of the Traffic Collision and Avoidance system on military transports contributed to the collision of a U.S. Air Force C-141 and a German C-130 off the coast of Africa in 1997. (See appendix 2 for further deatails)

C.6. Effects of Development Time on Cost

Long development times also impact the cost of the systems that we buy. It leads to higher development cost and less money being spent on producing the products. Conventional wisdom indicates that the longer the development time, the more a project will cost. The Packard Commission concurred, stating that "time is money, and experience argues that a ten-year acquisition cycle is clearly more expensive than a five-year cycle."[28] There is significant evidence of this effect in commercial development efforts.[29] Unfortunately, no data estimating the cost of different development schedules are available for specific military projects. The cost models now used by DoD and the services do not account for the effects of time.

Data on major defense acquisition projects available from RAND show a positive correlation between development time and cost. Of the ACAT I programs, those that take less than

[28] President's Blue Ribbon Commission on Defense Management. "A Formula for Action: A Report to the President on Defense Acquisition" (The Packard Commission Report) Washington D.C. April 1986. Pg. 8.

7 years to complete have an average development cost of $1.2 billion. Projects that take between 7 and 14 years have an average cost of $1.8 billion. Those taking over 14 years average $3.6 billion in development cost.[30]

[29] See discussion in Chapter 2.
[30] For the 123 projects in the RAND database with the necessary information, the Pearson correlation coefficient between the length of project schedules and cost of development is positive 0.25, with a two-tailed significance level of 0.005. This indicates that though there is considerable scatter in the data, longer programs on average do cost more.

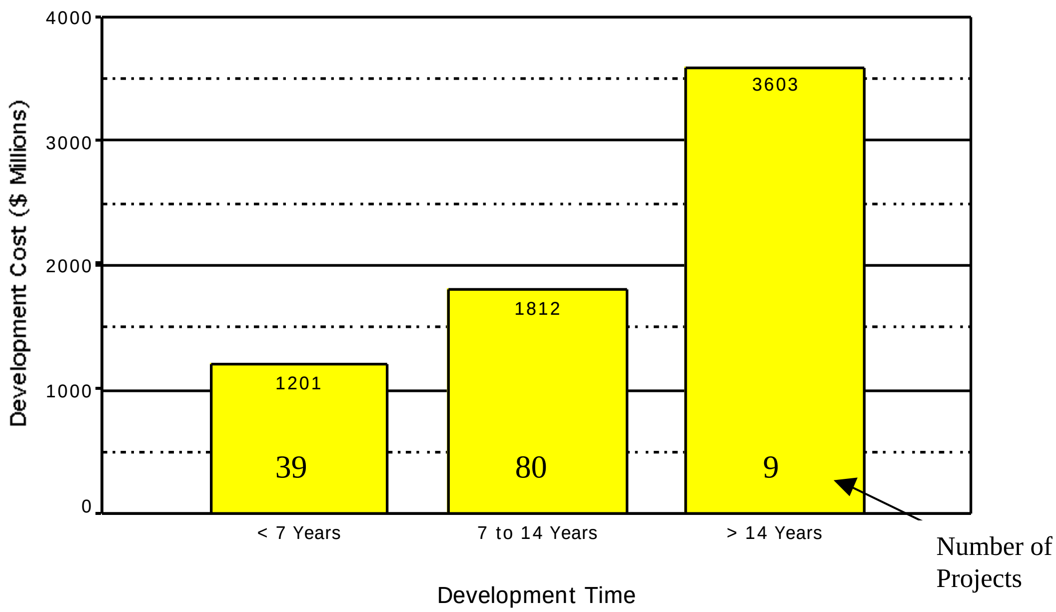


Figure 1-11: Cost by Years in Development for Major Defense Acquisition Programs (Data from Rand SAR Database).

Similarly, cost and schedule data on 154 projects of all sizes included in the surveys conducted as part of this research effort indicate that the correlation between development time and cost is both positive and statistically significant.[31]

More Funds Towards Development – Less Towards Production

Not only do longer programs cost more to develop but a larger percentage of the total project cost is consumed during development. Data from the RAND SAR database indicate that projects requiring less than 14 years of development time saw 27 percent of their cost go to development and 73 percent go to production. Projects with development times over 14 years had 46 percent of their cost go to development and 54 percent go to production. The high percentage applied towards developing the system results in less funds to actually produce the systems for the warfighter in quantity.

[31] Please see Appendix 2 for additional details.

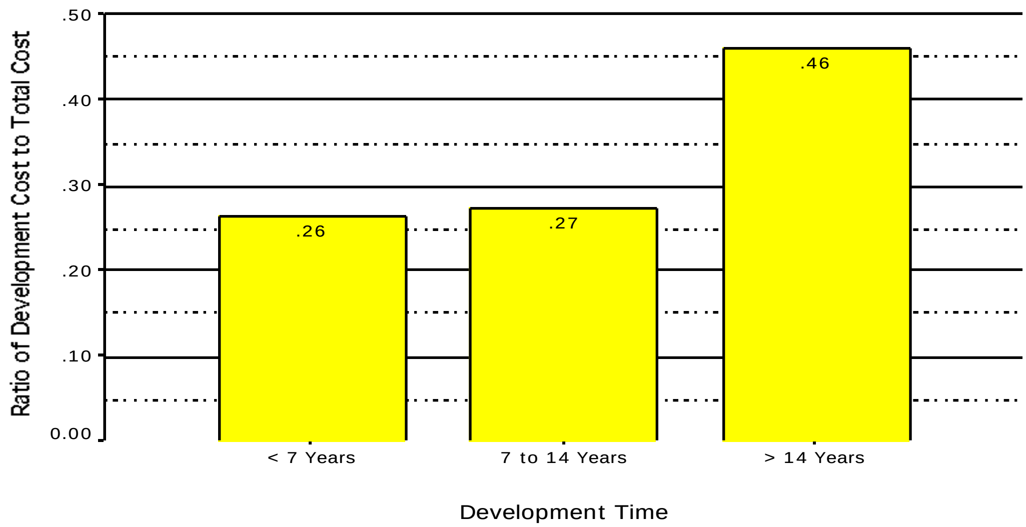


Figure 1-12: Percentage of Program Cost Going to Development and Production, by Development Time.[32]

As development programs have lengthened over the years, so has the percentage of DoD funding going to research, development, test, and evaluation (RDT&E). RDT&E funding for 1997 was $32 billion, representing 42 percent of total DoD investment funding (RDT&E plus production). This is the highest percentage ever. The rising percentage spent on RDT&E means that a smaller percentage is available for producing new systems or enhancing the operations, training, and readiness of existing forces. While both RDT&E and production funds have been cut significantly in the last 10 years, the RDT&E accounts have sustained smaller decreases. This has resulted in fewer new systems being fielded and made available for the warfighter.

C.7. Increased Program Instability and Cancellations

Increased Program Instability

Not only are long development times associated with higher costs, but the costs are less certain. Analysis of the Rand SAR database indicates that longer programs typically have larger percentages of cost growth than shorter programs. Programs taking less than 7 years to reach first operational delivery overrun their initial planned development budgets on average 15%. Programs

[32] Source of data: RAND SAR Database.

taking longer than 14 years on average overrun their development budgets by 42%.[33] This leads to additional program instability affecting these and other programs.

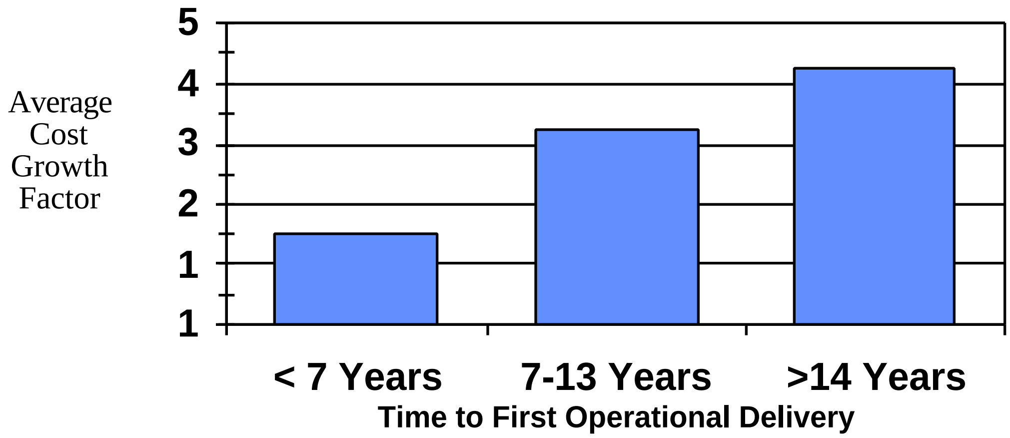


Figure 1-13: Average Program Development Cost Growth by Development Time. Analysis Based on Data From the RAND SAR Database.

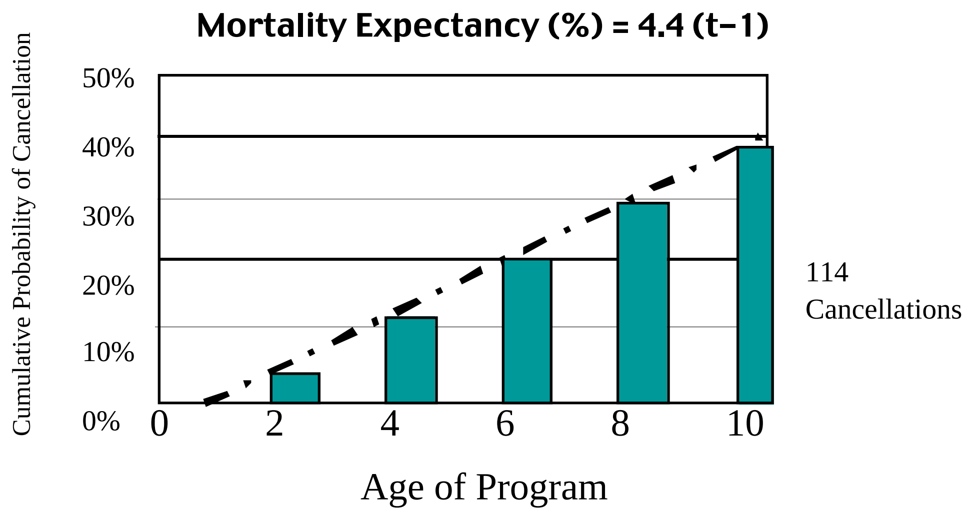
Increased Program Cancellations

Long development times also appear to increase the probability that a program will be canceled before entering production. All efforts to obtain information on canceled programs from the Pentagon were unsuccessful. The only data found comes from the book Augustine's Laws. According to Norm Augustine's analysis of 114 canceled programs, each program stands about a 4.4% chance per year of being canceled. Efforts to obtain the names and data on the canceled programs were unsuccessful. However, in a later article he cites representative examples of canceled programs including four canceled Army air defense systems: Mauler, Roland, Sgt York, and ADATS, none of which were fielded. These systems cost $6.7 billion in development costs and produced no combat capability.[34]

---

[33] J.M. Jarvaise, J.A. Drezner, and D.M. Norton. "The Defense System Cost Performance Database: Cost Growth Analysis Using Selected Acquisition Reports." MR-625-OSD Santa Monica CA: The RAND Corporation. 1996.

[34] Augustine, Norman. "From Industry…Acquisition Reform: Dream or Mirage." Army RD&A Magazine. September-October 1996. Pg. 20-22.



Norm Augustine ***Augustine's Laws***

Figure 1-14: Cumulative Probability of Cancellation of Defense Programs Over Time.[35]

Norm Augustine indicates the cost of these canceled programs in terms of lost military capability. He states the funds expended on the canceled programs "could have purchased 1,000 Abrams tanks, 100 F-16 Fighters, 1,000 AMRAAM Missiles, 10 Titan IV Rockets, 20 JSTARS, 10,000 Javelin Missiles, 70,000 MLRS Rockets, and One Nuclear Attack Submarine."[36]

Increased Management Turnover

One potential reason for the increased program instability and increased cancellations is the difficulty maintaining a consensus among a large number of program and service leaders over time. As shown in the table below, the average program taking 11 years to go from program initiation to initial operational capability has experienced a significant amount of management turnover.

---

[35] Augustine, Norman R. Augustine's Laws. American Institute of Aeronautics and Astronautics. Washington DC. 1983.

[36] Augustine, Norman. "From Industry…Acquisition Reform: Dream or Mirage." Army RD&A Magazine. September-October 1996. Pg. 20-22.

Number of: (132 Months Avg ACAT I)*		
Program Director	**4**	
Program Executive Officer		**5**
Service Acquisition Executive	**8**	
Defense Acquisition Executive	**8**	
Chairman of the Joint Chiefs of Staff	**5**	
Secretary of Defense		**7**
President	**3**	
Budget Cycles	**11**	

Table 1-3: Management Turnover for the Average Development Time for a Major Defense Acquisition Program.[37]

C.8. Increased Sustainment Costs

Long development times also contribute to increased cost of operations and sustainment. They increase the time required to replace systems that have high operating costs. One example is the DD-21 destroyer that is expected to lower the operating cost of a Navy destroyer by 70% compared to today's destroyers. Long development times increase the time to replace hard-to-maintain systems such as the current F-15 radar which has 12 hour Mean time between maintenance action. The upgraded radar systems under development are expected to have 120 hour mean time between maintenance action.[38]

Long development times also increased the impact of diminishing manufacturing base parts; and with long development times, the problems occur earlier in a system's life. One example is the F-22 which is approaching its production decision and currently has 593 parts which are already out of production. Replacing these parts in the design is expected to cost $279M.[39]

Anotherway that long development times impact sustainment of systems is that once a new program is started, it typically freezes upgrades to the existing systems. This is done in part to ensure a significant difference between the new system and the old system to justify the new system. Upgrades and modifications to existing systems must compete for the same scarce resources with new programs. Many examples exist, including fighter aircraft, satellite communications, bombs and missiles. Prior to the delivery of the new systems or in the event the new system is canceled, the warfighter is left with less-then-optimal equipment.

---

[37] Developed by looking at management turnover in key offices for the last 11 years.
[38] Information obtained from the F-15 Program Office in March 98.
[39] Information obtained from the F-22 Program Office in March 1998.

C.9. Other Impacts of Long Development Time

There are many other potential impacts of long development time. Samples will be mentioned but not covered in detail. Further analysis is contained in the Appendix 2 or left for subsequent work.

Increased requirements and specification due to uncertain threat forecasts

Increased technology step sizes

Increased number of programs in development at once

Increased competition for resources

Decreased management attention per project

D. Efforts to Shorten Development Times

While there has been a flurry of acquisition reform activity in recent years, little of this effort has been aimed primarily at reducing development time. The primary aim of the current acquisition reform efforts has been focused on lowering costs. Acquisition reform initiatives that focus primarily on cost include cost as an independent variable (CAIV), elimination of military specifications and standards, single-process initiative (SPI), performance-based specifications, clear accountability in design, and the manufacturing development initiative. These initiatives may also affect development time, though indirectly. A few efforts have aimed at shortening acquisition schedules, including the Packard Commission and the Affordable Acquisition Approach Study. These efforts are outlined below.

D.1. Previous Efforts

Many reports, teams, and commissions have, in one way or another, attempted to address the DoD development problem. Most have focused on long production schedules and high costs. Many have focused on the inability to meet projected schedules. Those efforts include the influential Packard Commission and the current National Performance Review. But although reform efforts have focused on long development times since the late 1970s, none appear to have had significant effect.

Affordable Acquisition Approach Study

The Air Force Systems Command Affordable Acquisition Approach completed in 1983 focused on two questions: "Are projects taking longer? and what can be done about it?". The study found that development times had increased significantly over the previous 30 years. The study also found that the major cause of lengthening development and production times was the over commitment of resources within the Air Force budget.[40] The emphasis on development time decreased as the study progressed and is evident in the change of the project's name from its original name as the Accelerated Acquisition Approach Study to the Affordable Acquisition Approach Study. One notable participant was the contract leader, Dr. Jacques Gansler, the current Defense Acquisition Executive. Few identifiable actions resulted from the study.

The Packard Commission

The 1986 Packard Commission looked at the entire defense acquisition process, citing long development times as the central problem from which most other acquisition problems originate. The Packard Commission's stark assessment identified problems at all levels, from program managers to Congress. It's major recommendations were to cut acquisition time in half by emulating successful commercial firms with world-class customers. In its *Formula for Action*, the Packard Commission stated:

> Acquisition problems have been with us for several decades, and are becoming more intractable with the growing adversarial relationship between government and the defense industry, and the increasing tendency of Congress to legislate management solutions. In frustration, many have come to accept the ten-to-fifteen years acquisition cycle as normal, or even inevitable.
>
> We believe that it is possible to cut this cycle in half. This will require radical reform of the acquisition organization and procedures. It will require concerted action by the Executive Branch and Congress, and full support of the defense industry. Specifically, we recommend that the administration and the Congress join forces to implement the following changes in the defense acquisition system.[41]

To achieve this goal, the commission recommended streamlining acquisition organizations and procedures, using technology to reduce costs, balancing performance with costs, stabilizing programs, expanding the use of commercial products, increasing competition, and raising the quality of acquisitions personnel. The commission further aimed to consolidate acquisition efforts under the Office of the Secretary of Defense (OSD), create acquisition executives at the assistant

---

[40] Air Force Systems Command. "Affordable Acquisition Approach." Andrews AFB MD. 1983.

[41] President's Blue Ribbon Commission on Defense Management. "A Formula for Action: A Report to the President on Defense Acquisition" (The Packard Commission Report) Washington D.C. April 1986. Pg. 15.

secretary level for each service, and rely on executive officers to oversee major projects within the services. The commission also established rigid objectives for cost, schedule, and performance for all major programs, and advocated standards and training programs. President Reagan quickly accepted the commission's recommendations, and Congress, which had been eager for acquisition reform, quickly turned them into law.

With the bold charge to cut acquisition time in half, strong support from the president and Congress, and quick response by DoD, one would have expected dramatic results. However, although DoD implemented the commission's recommendations, it did not widely internalize the goal of slashing development time. Few of the people I interviewed realized that reducing development time was even a significant objective of the Packard Commission. The current focus of acquisition reform efforts is clearly on cutting costs, not reducing development time. Only a few of the hundred or so current reform initiatives are aimed at reducing development schedules.

D.2. Recent Efforts to Shorten Product Cycle Time

Nevertheless, three recent efforts directly address product development time: Air Force Acquisition Reform Initiative ("Lightning Bolt #10"), the DoD Advanced Concept Technology Demonstrations (ACTDs), and the Lean Aerospace Initiative, a consortium involving industry, government, and academia of which this research is a part. Two new initiatives, the Defense Systems Affordability Council Acquisition Cycle Time Reduction Task Force, and the Air Force Cycle Time Reduction Tiger Team, are focused directly on reducing development time.

AF Lightning Bolt Initiative #10

Just after his confirmation in 1996 as Assistant Secretary for Acquisition, Arthur Money began a new initiative to cut the time to develop and field new Air Force systems in half. The description of Lightning Bolt #10 in March 1996 read:

> Lightning Bolt #10. The time from initial effort by a buying office to satisfy a user's validated requirements (for a new product, services, parts, etc.) until delivery will be reduced by 50% [42]

However, the project's scope was soon narrowed from cutting the time from receipt of requirements and allocated funds to contract award in half. The acquisition community therefore

[42] Air Force Acquisition Reform Online newsletter March/April 1996.

limited the complicating factors and focused only on those parts under its control.[43] The objective of the initiative was changed to read:

> Reduce by 50% the amount of time to award contracts that meet our customers' needs. This time begins with receipt of a validated user requirement and funding commitment, and ends with contract award. Lightning Bolt #10 applies to efforts to develop and acquire systems, and support their operational readiness.[44]

The Lightning Bolt #10 group conducted interviews with program managers and documented a set of best practices and new ideas to reduce time to contract award. The Lightning Bolt #10 group disbanded after issuing its report and placing its "tool box" of ideas on the Internet.

Advanced Concept Technology Demonstrations (ACTDs)

Advanced Concept Technology Demonstrations, an initiative of the Office of the Secretary of Defense (OSD), are designed to reveal the utility of readily available technologies for meeting pressing military needs. The idea is to allow the warfighting community to evaluate a technology's military utility before committing to a major development effort. The OSD expects these demonstration programs to last between 2 and 4 years.

Paul Kaminski, former Under Secretary of Defense for Acquisition and Technology, envisioned the program as a way to compress the time required to develop and field weapon systems and to stimulate innovations needed to implement a revolution in military affairs.[45]

ACTDs are expected to reduce cycle time by allowing an acquisition process to begin at Milestone II—the beginning of full-scale development. Former Under Secretary Kaminski also points out that because they are not part of the official acquisition process, ACTD projects can incorporate considerably more flexibility in their contracts as they do not fall within the formal rules of an acquisition program and are often able to use a different procurement category. After completing an ACTD, the warfighting commanders can recommend proceeding to low-rate initial production, pursue additional demonstration to improve the technology's performance, or drop the technology.

---

[43] Personal discussion with Col Ben McCarter. Lightning Bolt 10 Leader. 13 June 1996.
[44] Air Force Acquisition Reform Online newsletter June/July 1996.
[45] Kaminski, Dr. Paul G. "Advanced Concept Technology Demonstrations: Challenges and Opportunities." Keynote Address, ACTD Managers Conference, DSMC, Fort Belvoir, VA, Sept 10, 1996.

DoD now provides a financial incentive for services to conduct ACTDs by adding 10 percent to what a service commits, although the number of ACTDs is limited by total DoD funding. As of 1997, some 15 small development efforts are operating under the ACTD model--a small but visible effort. However, this approach is intended to circumvent the official development process, not change the process used to develop most systems and projects.

The Lean Aerospace Initiative (LAI)

The Lean Aerospace Initiative, a consortium encompassing industry, government, labor, and academia, is led by the Massachusetts Institute of Technology, where 17 professors, 9 full-time research staff, and over 20 graduate student research assistants work under the LAI purview. The program is intended to reduce cost, development, and production time for military products by half by infusing commercial lean practices throughout the defense aerospace industry. Participants are conducting research in all phases of the development and manufacturing process, including factory operations, supplier relations, and government policy.

This approach contrasts with most efforts to reduce development time, which often focus only on certain aspects. The figure below maps the cycle time-related initiatives against the phases of the development effort that they effect.

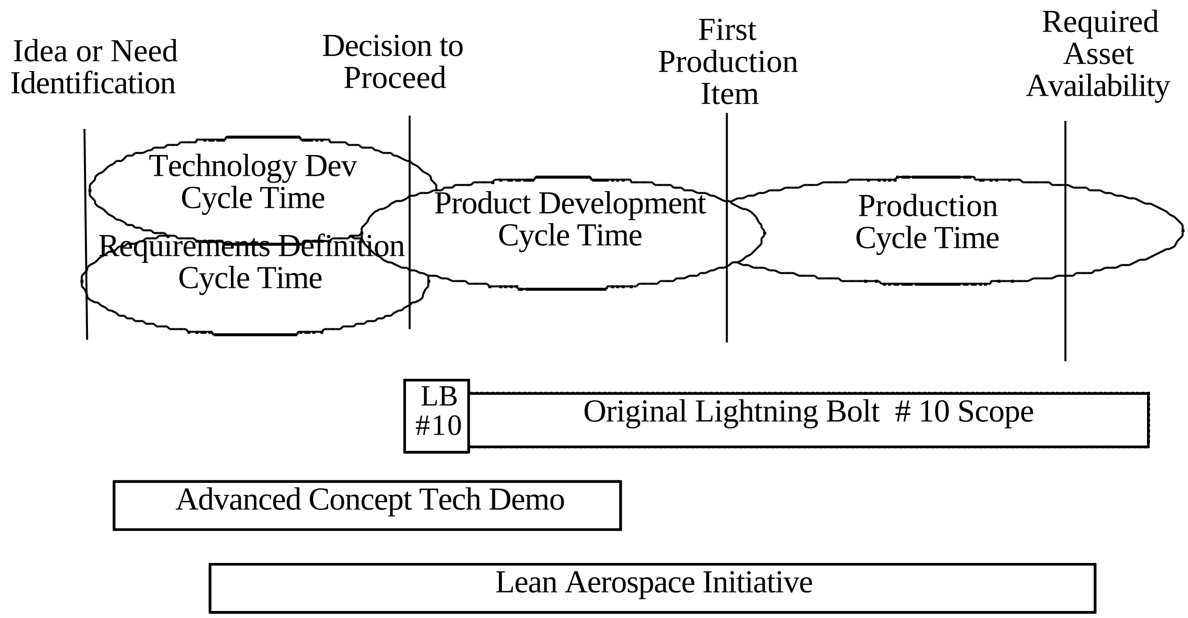


Figure 1-15: Mapping of Current Cycle Time Reduction Efforts

D.3. New Cycle Time Initiatives

In the late fall of 1997, two new programs, one at the DoD level and one at the Air Force level, were initiated to help address long development time. DoD's Acquisition Cycle Time Reduction Task Force aims to cut the period from project initiation to initial operational capability for major systems in half. The Air Force Cycle Time Reduction Team aims to dramatically cut the time to develop and field new and modified systems. This research has shaped a significant portion of these efforts.[46]

[46] Note: The author is the Air Force Representative on the DoD Cycle Time Reduction Task Force and the Co- leader of the Air Force Cycle Time Reduction Team.

Chapter Summary

The Packard Commission identified long cycle time as the central problem in the acquisition process. Development times for military systems have increased significantly over the last 30 years. Current development times for major defense acquisition programs is approaching 115 months. Time from program initiation to initial operating capability (when the system is ready for use) is even longer. The time required to develop or modify major military systems is now approaching 11 years. Long development cycles affect warfighters as systems long in development are not available for use, the technology included in these systems when fielded is dated, the time to meet new threats is long, and the time to fix identified problems is long. Long development times also impact the cost of developing and maintaining weapon systems. Long development times also cause program uncertainty as costs are less certain, more programs are canceled, and leadership changes as do leadership priorities.

While several studies have attempted to identify the causes of long cycle times, they have had little effect, as development times have continued to grow. Part of the problem is that most of the reform initiatives focus solely on cutting the cost of weapons. Few of the current initiatives focus on reducing development or acquisition response times. What’s more, two of the three initiatives to reduce development time address only part of the problem. Clearly much needs to be done if the time required to develop new military systems is to be significantly reduced.

Chapter 2

Commercial Efforts to Reduce Product Development Time

A. "An Acquisition Model to Emulate"

Commercial companies and practices are often held up as a model for the DoD acquisition system. The Packard Commission, for example, referred specifically to an analysis by the Defense Science Board of large commercial development programs. The board evaluated several multi-year, multi-billion-dollar programs comparable to the complex efforts required to develop major military systems. The commercial projects included the IBM 360 personal computer, the Boeing 767 transport, the AT&T telephone switch, and the Hughes communications satellite. The Defense Science Board study found that these projects were completed in half the time required for similar DoD development efforts, and cost concomitantly less.[47] The Packard Commission noted that "These commercial programs clearly represent the models of excellence we are seeking . . ." The commission also cited several defense projects, such as the Polaris and Minuteman missiles, that had achieved the accelerated schedules of commercial programs. Based on these results, the commission concluded that it was possible to apply commercial lessons to the Department of Defense. The commission stated:

> It is clear that major saving are possible in the development of weapons systems if DoD broadly emulates the acquisition procedures used in outstanding commercial programs. In a few programs, DoD has demonstrated that this can be done. The challenge is to extend the

[47] President's Blue Ribbon Commission on Defense Management. "A Quest For Excellence: A Report to the President on Defense Acquisition" (The Packard Commission Report) Washington D.C. April 1986. Pg. 11.

correct management techniques to all major defense acquisitions, and more widely realize the attendant benefits in schedule and costs.[48]

The commission identified six management features necessary to cut cycle time and cost: clear command channels, program stability, limited reporting requirements, small but high-quality staffs, good communication with end users, and effective prototyping and testing. The Commission made specific recommendations in these areas, which were implemented. But, as we have seen, development times for military systems have not decreased, indicating either a problem with implementing the recommendations or other critical factors associated with commercial projects not addressed by the Packard Commission. Dramatic changes have occurred in the commercial product development world since the Defense Science Board and Packard Commission issued their reports. More efficient and effective development time has become the competitive focus of many of the most successful firms.

B. Competing on Product Development Time

In the last 15 years, the time required to develop and market commercial products has been dramatically reduced. Firms are competing not only on price but also on their ability to quickly produce high-quality products that meet the changing needs of their customers.

Commercial firms have found that by reducing time to market, they can also lower costs. This has allowed companies to expand the number of new products they develop. The result is a wider array of products that cost less than their predecessors.

Companies with fast product development abilities have a number of options open to them. They can deliver a product to market before their competitors, thereby capturing market share and setting industry standards. Alternatively, they can choose to start a project after a competitor but deliver it to market at the same time--with more cutting-edge technology or specific attributes that meet customers' needs. Fast product development times also allow a company to quickly respond to a new product introduced by a competitor. The ability to develop and manufacture products quickly allows a company to select from a number of competitive strategies not available to companies with significantly longer development times.

A number of books have recently appeared on the subject of reducing product development time. Two of the more popular are *Revolutionizing Product Development*, by Kim Clark, and *New Product and Process Development*, by Steven Wheelwright. Others include *Developing*

[48] President's Blue Ribbon Commission on Defense Management. A Quest For Excellence: A Report to the President

Products in Half the Time, Lightning Strategies for Innovation, Competitiveness Through Total Cycle Time, *Fast Cycle Time, and Survival of the Fittest: New Product Development for the 90s.*[49] All these books focus on reducing cycle time as a critical method for improving commercial performance.

Competing on time to market is not limited only to consumer products; some companies in the defense industry also rely on this approach. Firms involved in communications, satellites, computers, and aircraft, for example, have all cut product development times.

Of all these, the automobile industry's efforts to reduce product development times are the most thoroughly documented. Major research on the automobile industry, such as the MIT International Motor Vehicle Program and the Harvard Automobile Study, has revealed detailed information on how these efforts have succeeded.

C. Reducing Product Development Time in the Automobile Industry

In the late 1980s, Japanese automobile companies maintained a substantial lead over American and European companies in product development and manufacturing. The Japanese were able to develop and produce higher-quality cars, with more newly designed parts, in significantly less time, with significantly fewer people, at significantly lower cost, than their U.S. competitors. These advantages allowed the Japanese to offer significantly more new models and model upgrades each year, and to rapidly include new features and technologies demanded by customers. This, in turn, enabled them to dramatically increase their market share at the expense of their U.S. competitors, who struggled for their very survival. Table 2-1 provides a view of the product development performance of Japanese and American automobile manufacturers in the mid-1980s. The table shows that the Japanese developed new models using only 68 percent of the time required by U.S. companies. This allowed the Japanese to start a new development project one and a half years later than an average American company yet bring it to market at the same time.

Japanese companies developed equivalent, if not superior, cars with roughly one-third the engineering hours and used only 485 engineers per project compared with 903 at U.S. firms--figures that account for the majority of development costs. Ratings by services such as JD Powers and Associates attested to the significantly higher quality of the Japanese vehicles. Japanese companies also found not only that they could undertake more development efforts with a given level of resources, but that they maintained more control over their development efforts. The result

on Defense Acquisition (The Packard Commission Report) Washington D.C. April 1986. Page 12.

[49] For full bibliography information, please see the reference section in Appendix 5.

was significantly fewer delayed products (one in six) than their American counterparts (one in two).

Automobile Producers	**Japan**	**U.S.**
Average Development Time (Months)	42.6	62.0
Average Engineering Time (Millions of Hours)	1.2	3.5
Total Product Quality (Rating)	58	41
Number of Employees in Project Team	485	903
Number of Body Types per New Car	2.3	1.7
Average Ratio of Shared Parts	18%	38%
Supplier Share Engineering	51%	14%
Engineering Change Costs (As Share of Total Die Cost)	10-20%	30-50%
Ratio of Delayed Products	1 in 6	1 in 2
Return to Normal Quality After New Model (Months)	1.4	11

Table 2-1: Product Development Performance of U.S. and Japanese Auto Industries (Mid-1980s)[50]

When analyzing the performance of Japanese and American companies, for example, Kim Clark and Takahiro Fujimoto[51] found that the Japanese were not "buying" lead time by using additional resources, as had been expected.[52] Instead, they found a positive correlation between speed and efficiency: faster firms were more efficient and slower firms were less efficient.[53] This result may have been partly due to the ability to use the design-build-test cycle to quickly identify and eliminate problems. Clark and Fujimoto noted:

> Time-To-Market is such a critical dimension of performance in the outstanding project, that all of the processes, systems, and activities are geared to fast action. This is particularly true for the critical design-build-test cycles that are at the heart of problem solving in development . . .[54]

Japanese automakers used their product development ability to increase the number of models they offered from 47 in 1982 to 84 in 1990. American automobile manufacturers, in

---

[50] Composite data from Product Development Performance and Womack, Jones, and Roos. The Machine that Changed the World: The Story of Lean Production. New York: Harper Perennial. 1990. Pg. 118.

[51] Kim Clark and Takahiro Fujimoto. Product Development Performance: Strategy, Organization and Management in the World Auto Industry. Boston MA: Harvard Business School Press. 1991.

[52] The idea of buying leadtime was widespread in DoD programs and is called "crashing a program" by applying additional resources to shorten the schedule.

[53] Kim Clark and Takahiro Fujimoto. Product Development Performance: Strategy, Organization and Management in the World Auto Industry. Boston MA: Harvard Business School Press. 1991.. Pg. 87.

[54] Kim Clark and Takahiro Fujimoto. Product Development Performance: Strategy, Organization and Management in the World Auto Industry. Boston MA: Harvard Business School Press. 1991. Pg. 304.

contrast, increased their offerings from 36 in 1982 to 53 models in 1990. During this same period, the Japanese were replacing their models on average every 4 years, while the American manufacturers were replacing their models on average every 10 years.

By updating their models more quickly, the Japanese were able to adapt and market new technologies faster than U.S. companies. They also could quickly incorporate new and cheaper manufacturing processes, and build on lessons from the previous generation. Japanese product development performance allowed them to enter market areas in force, such as the luxury car market, with new lines such as the Lexus and Infinity, that compete effectively with established brands in this profitable sector.

The Japanese focus on reducing development time played a central role in this success. Clark and Fujimoto indicated the impact of a focused effort on cutting development cycle time:

> Faster Development Time -- A Unifying Driver. Just as engineers need a vision of the overall product to guide their efforts in developing a new car, the people involved in changing the development organization need a vision, an objective that captures their imagination. Where changes have taken hold and worked, senior managers have linked the need for a new organization to competition and the drive for tangible results in the market place. The quest for faster development lead-time has been a particularly powerful driver of this effort during the 1980s. Lead-time is not an end in itself, but its pursuit leads people to do things that improve the system overall. In respect, lead time is like inventory in a Just-In-Time manufacturing system; of itself, a low level of work in progress inventory has some effect, but going after the root causes of excess inventory brings about powerful system changes.[55]

Finding themselves at a severe competitive disadvantage, U.S. automakers responded quickly to the crisis in the early 1990s and significantly reduced their product development times, which are now less than two years for a new car. The variety of U.S. vehicles has dramatically increased, and quality has never been higher. Cars are lasting longer, and their costs are actually declining.

D. Reducing Product Development Time in Other Industries

Automobiles are not the only industry to significantly reduce its product development time; that focus is spreading to nearly every sector. The driving forces behind this phenomenon are intense international competition, fragmented and demanding markets, and diverse and rapidly

[55] Clark, Kim and Takahiro Fujimoto. Product Development Performance: Strategy, Organization and Management in the World Auto Industry. Boston MA: Harvard Business School Press. 1991. Pg. 282.

changing technologies.[56] The result of this competition has been an explosion in product variety, dramatic increases in quality, and large decreases in costs over a wide range of industries, from textiles to consumer electronics. These developments have also affected commercial sectors related to the defense industry, such as the commercial aircraft, satellite, computer, and communications industries.

The commercial aircraft industry is seeing significant competition in several categories, from business jets, to regional jets, to widebody jets, in part because of decreases in product development times. Boeing produced the 777 in five years during the 1990s. Boeing has now set an aggressive goal to reduce development time for future aircraft to two and a half years for new aircraft and 18 months for modifications to existing aircraft.[57] Such a focus gives all groups within the firm a clear and effective measure of performance.

The commercial communication satellite industry has also seen a large reduction in cycle times. Hughes Aircraft Co. states that it can develop and launch a new satellite that responds to a specific customer's needs in as little as 18 months. Previous development times exceeded five years.[58] Similarly, computer companies have cut product development cycles to less than six months to keep up with rapidly changing technology.

---

[56] Kim Clark and Steven Wheelwright. Revolutionizing Development: Quantum Leaps in Speed, Efficiency, and Quality. New York: The Free Press. 1992..

[57] Walt Gillette, Boeing Commercial Aircraft Company. MIT Seminar. Fall 1997.

[58] Hughes Spacecraft. Effort known as “Project 18,” representing 18 months from contract to on-orbit operations.

Industry	Old Time	Current	Goal
Automobile	**7 years**	**2 years**	**<18 months**
New Commercial Aircraft	**8-10 years**	**5 years**	**2 1/2 years**
Commercial Spacecraft	**8 years**	**18 months**	**12 months**
Consumer Electronics	**2 years**	**6 months**	

Table 2-2: Various Industry Product Development Times and Goals.

Of course, the purposes of military systems and commercial systems differ. The motivations of commercial firms--profits and market share--differ from that of the DoD of providing the most effective defense. However, the means to achieve those objectives are similar: to develop and field the highest-quality, lowest-cost systems that meet customers' needs. The fast commercial time-to-market competitor can charge a price premium for a new product with higher quality or additional features until a competitor matches the offer. Alternatively, manufacturers can decide to increase market share by offering better performance for the same price. The slow competitor does not have these options. The same is true for DoD: if it can deliver a better system with more advanced technology that meets warfighters' needs faster than an opponent can field a counter system, the U.S. can achieve a significant military advantage. This fact was not lost on Under Secretary Kaminski, who told a Senate subcommittee: “The military advantage goes to the nation who has the best cycle time to capture technologies that are commercially available; incorporate them in weapon systems; and get them fielded first.”[59]

This view is shared by at least some defense industry leaders such as G. Dean Clubb, head of Texas Instruments' Defense and Electronics Group, who wrote: “As the pace of the world quickens, the value of being first to market with innovative solutions is the key to true competitive advantage. This is true in the commercial market place and it is also true in the military market.”[60]

---

[59] “Statement of The Under Secretary of Defense for Acquisition and Technology, Paul G. Kaminski before the Subcommittee on Defense Technology,” Acquisition and Industrial Base of the Senate Committee on Armed Services on Dual Use Technology. May 17, 1995.

[60] G. Dean Clubb, “Blinding Speed Equals Competitive Advantage.” *Acquisition Review Quarterly*. Fall 1996.

Chapter Summary

The commercial industry has been often cited as an example for DoD to emulate. The commercial industry has made great strides in reducing development times. They have done this for competitive reasons and the requirement to quickly meet their customers' changing needs with high quality and low-cost products. The focus on the reduction of development time is seen as an organizing focus from which to organize development efforts. They have found that by focusing on the reduction of development time, they force dramatic improvements in their business processes. This has resulted in higher-quality products, at lower cost, in dramatically less time. Reductions in development times are often between 50% and 75% in many industries, even in industries closely related to the defense industry.

Chapter 3

The Air Force Product Development Process

This chapter provides an overview of the various organizations, stages, and processes involved in the current Air Force product development process. It is intended to provide an understanding of the actors and their roles in the process of developing a procurement schedule, which is described in later chapters. The description provided here is quite general, and any individual development project may follow a slightly different path.

The description is based on federal, DoD, and Air Force regulations and instructions, published books on the defense acquisition process, material for acquisition training courses from industry and specific companies, interviews and discussions with a wide range of people, and personal experience within the acquisition process. Appendix 3 contains references as well as additional details on each process.

A. Core Product Development Processes

Air Force product development processes can be separated into six distinct stages: identifying the need, developing the requirements, allocating resources, planning the acquisition, contracting, developing the product and establishing the process to produce it.

Force planning determines which systems are needed. Requirements determine what the new system must do to meet the need. Resource allocation determines the funding for the development effort, given the range of activities and responsibilities of the services. Acquisition planning entails determining how the system will be contracted and creating the plan to develop the system. Contracting entails selecting the contractor to develop the product and specifies the contract conditions. Development turns the ideas, requirements, resources, and plans into a working system that can be produced.

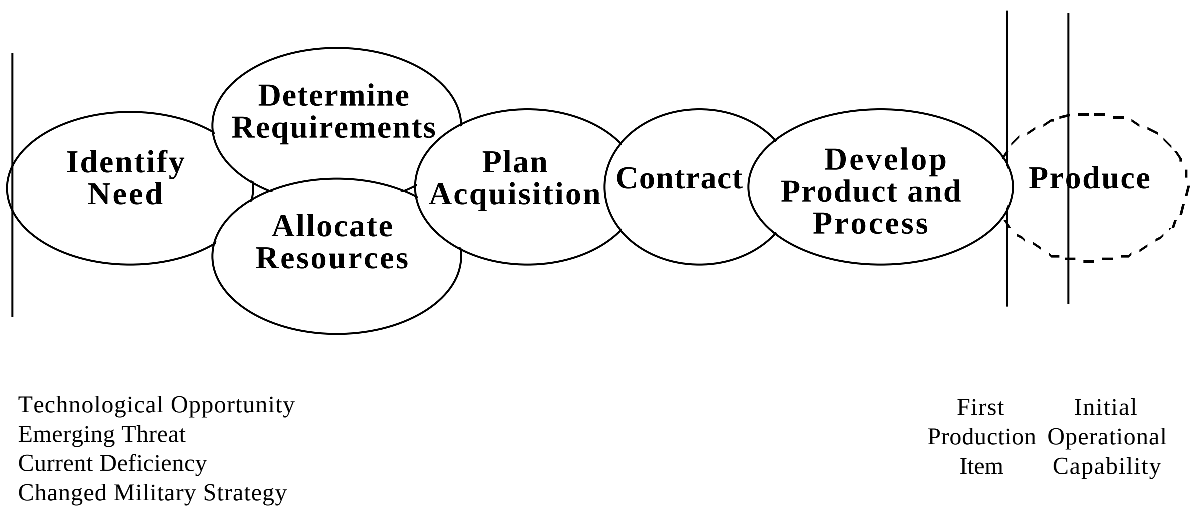


Figure 3-1: Major Steps in the Air Force Product Development Process.

Identification of need begins when an operational deficiency, an emerging threat, a technological opportunity, or a change in military strategy occurs. Influences at this stage include the Pentagon's long-range planning, the major commands' modernization planning process, and priorities of the senior leadership. A "mission needs statement" specifically identifies the need, which leads to a Milestone 0 decision authorizing further analysis and determination of system requirements. To determine those requirements, the major commands provide an analysis and obtain the Pentagon's approval. The result is an "operational requirements document" outlining what a new system must do.

The major commands' resource planning process and the Pentagon's programming, planning, and budgeting systems identify the dollars, equipment, and number of people authorized for the project. The result is a program objective memorandum and a requested budget sent to Congress. The program offices then develop an acquisition plan and obtain approval within the Pentagon. This results in a Milestone I decision authorizing contracting and development efforts.

A Program Office then produces a request for proposals (RFP) and selects the winning proposal from those submitted by contractors. The result is a contract that describes the specifications for the project and the terms under which the contractor will pursue it.

The contractor then designs both the system and the process used to produce it. The program office oversees this process and the Pentagon oversees the Program Office. Completion of development is marked by delivery of the first production item. Each of these major areas will be described in more detail later in the chapter.

The acquisition process typically proceeds through formal phases and milestones designed to allow for periodic review. Need identification occurs in the Pre-Milestone 0 phase. Setting requirements, allocating resources, and performing early acquisition planning occur during Phase 0. The contracting and the development efforts occur during Phases I and II. The development effort is typically complete by Milestone III or the production decision that marks the beginning of Phase III. Milestone II and Milestone III decisions are administrative-based decisions that do not always tie directly to event-based milestones in the development process. Figure 3-2 below shows the relationship between the process areas and the milestone phases.

An overall metric of this process is acquisition response time: the time from when the need arises to the time when the system is fielded and ready for use. Development time is the major component of acquisition response time.

Understanding this complex process requires a more detailed look at the organizations and sub-processes involved.

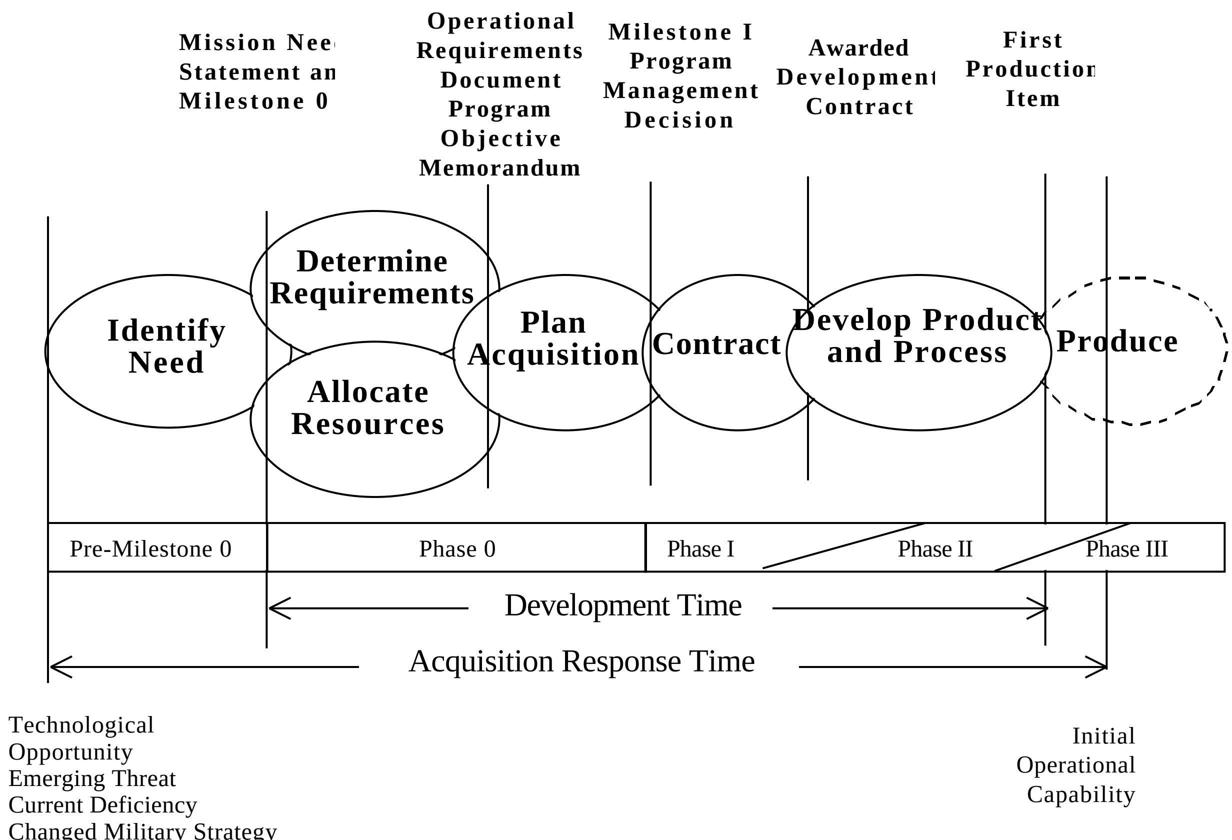


Figure 3-2: Major Steps in the Air Force Product Development Process.

B. Organizations Involved in Development

The organizations primarily involved in developing defense systems are the users, the service headquarters, the Program Offices, and the defense contractors. Each group plays a different role during various stages, and still more organizations play secondary roles. Figure 3-3 shows the distribution of various sub-processes by the organizations primarily responsible for them.

The users--the ultimate customers--do much of the planning and establishing of requirements. The users are organized by different Air Force mission areas into major commands such as Air Combat Command (ACC), Air Mobility Command (AMC), and Air Force Space Command (AFSPC); or by geographic area such as US Air Force Europe (USAFE) and Pacific Air Forces (PACAF). A major command's mission is to organize, train, equip, and maintain combat-ready forces for use by the Unified commands, such as US Central Command, which are composed of units of all the services.

Each of the major command headquarters has planning offices that project future needs, requirements officers who identify future requirements for systems, and programming offices that project the budget for major command activities. (These roles will be discussed in detail below.) The officers in these positions are typically from the operational units within the major command.

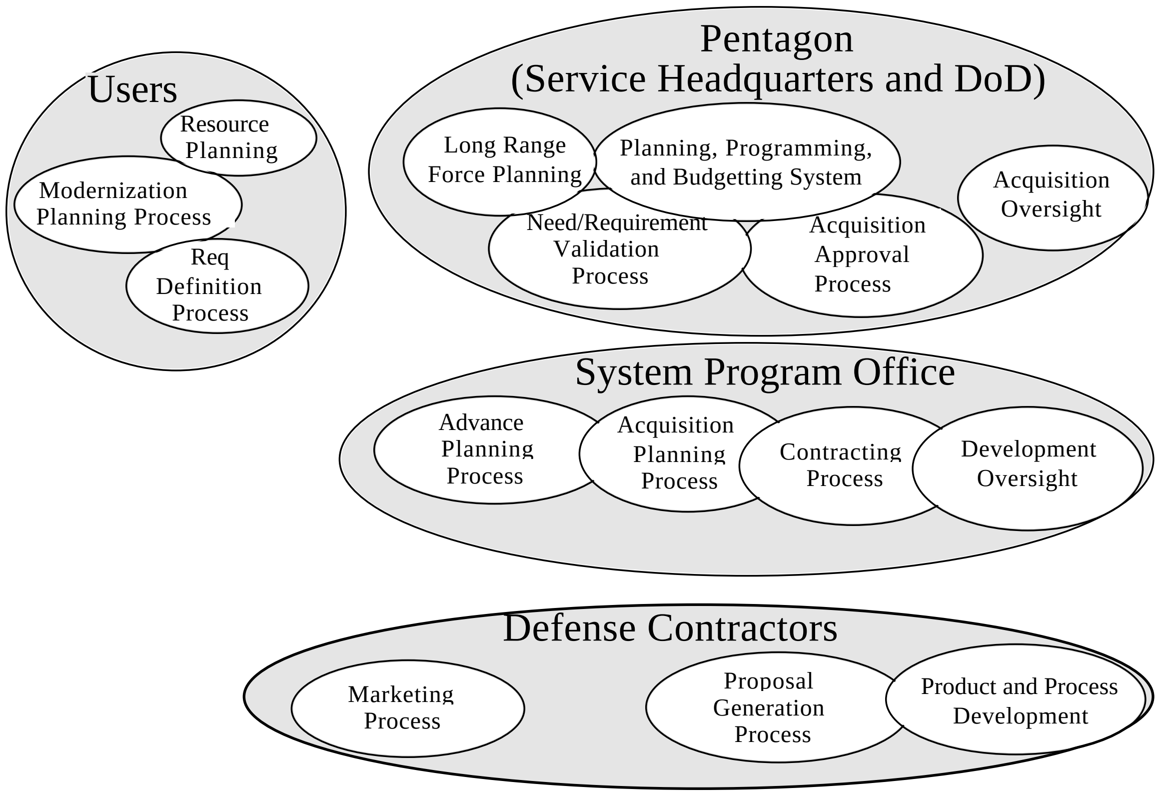


Figure 3-3: Major Product Development Processes by Organization

The service headquarters and the Department of Defense together compose the Pentagon. Each service headquarters is the approval authority for the planning, requirements generation, and the acquisition plans. They also allocate resources and oversee the various development efforts. Each function is duplicated at the DoD level, with the Office of the Secretary of Defense and the Joint Chiefs of Staff playing an integrating, authorizing, and oversight role. DoD typically becomes involved at this level only with the largest defense acquisition programs and those with joint service application.

Many functional and cross-functional organizations fulfill the service headquarters' role in the development effort. Those organizations are divided between the secretariat and air staff. The key organizations include the Deputy Chief of Staff for Plans and Programs, the Assistant Secretary for Acquisition, the Assistant Secretary for Financial Management, and the Director for Program Integration. Headquarters-level groups such as personnel, manpower, logistics, C4I, and test also become involved through several organizations such as the Working and Overarching Integrated Product Teams and the Requirements Review Councils. These organizations are the primary interface with senior Air Force leaders, DoD, and external organizations such as Congress and the administration.

The System Program Offices oversees planning and contracting for major weapon systems or groups of similar weapons, and act as the primary interface with the contractor community. Program Offices are supported by Development Centers and Logistics Centers, which provide the necessary personnel. Each Program Office typically oversees many product development efforts.

Before developing a new product, defense contractors must win the contract. This involves several organizations within the company: marketing, typically referred to as the business development group; the proposal development team; and the integrated product team, which develops the actual product and processes. Financial management, engineering, and manufacturing groups oversee the company's development efforts.

Many other entities such as the testing community, the defense laboratories, and various defense think tanks also influence a development project but play a secondary role. Higher-level decision makers such as the administration and Congress are primarily involved in funding decisions for major development efforts and typically not in the details.

C. Identification of Needs

In the Air Force, the long-range planning group within headquarters Air Staff, the modernization planning process through the major commands, and an ad hoc process based on direction from senior leadership identify current and future needs. Needs based on current and future threats, military strategy, current military capabilities, and available technology are documented and approved through the mission needs statement, which in turn feeds the requirements and resource-allocation processes.

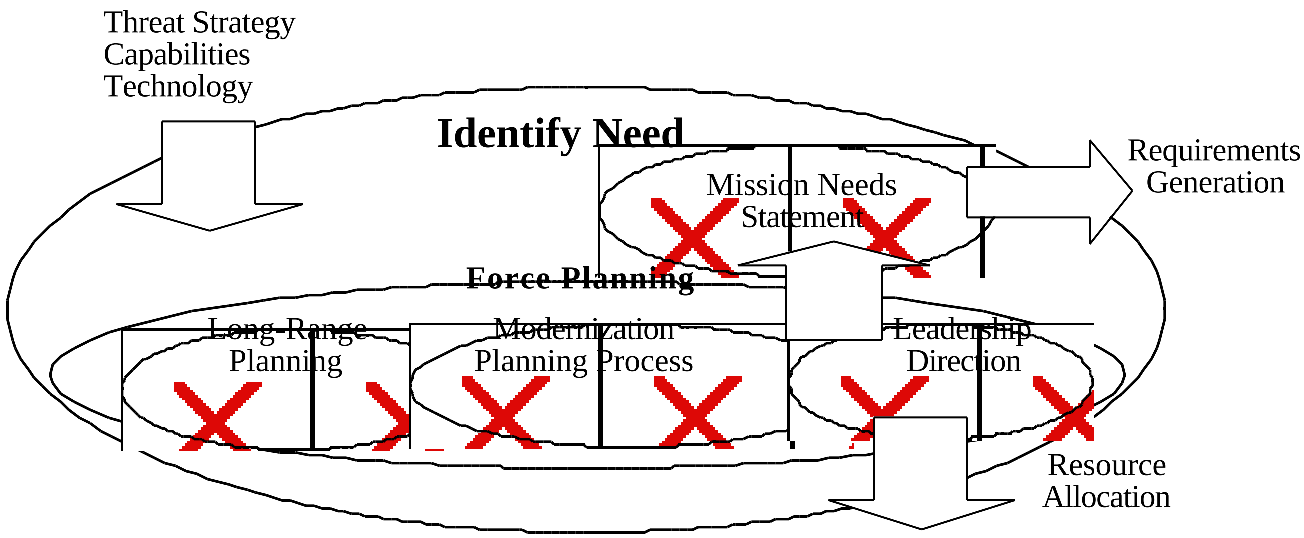


Figure 3-4: Components of Identifying Needs and Force Planning.

C.1. Long-Range Planning

The Pentagon's Strategic Planning Office was established in 1996 to focus on a 25-40 year time frame. This new organization has not yet had a significant impact on product development but may in the future.

C.2. Air Force Modernization Planning Process

The modernization planning process determines Air Force needs for new or improved capabilities to ensure that the service can accomplish its mission, including the president's national security strategy and national military strategy. The process used to convert the national military strategy into the required weapon systems is referred to as "strategy-to-task." Once the tasks are defined, the planners evaluate the capabilities of existing forces and identifies requirements for new and upgraded systems. This process is referred to as "task-to-need." (The processes used to accomplish the "strategy-to-task" and the "task-to-need" analyses are defined in several documents, including the CJCS MOP 77 *Requirements Generation System Policy and Procedures*, Air Force Directive AFPD 10-14 *Modernization Planning, and Air Force Instruction* AFI 10-1401 *Modernization Planning Documentation.*)

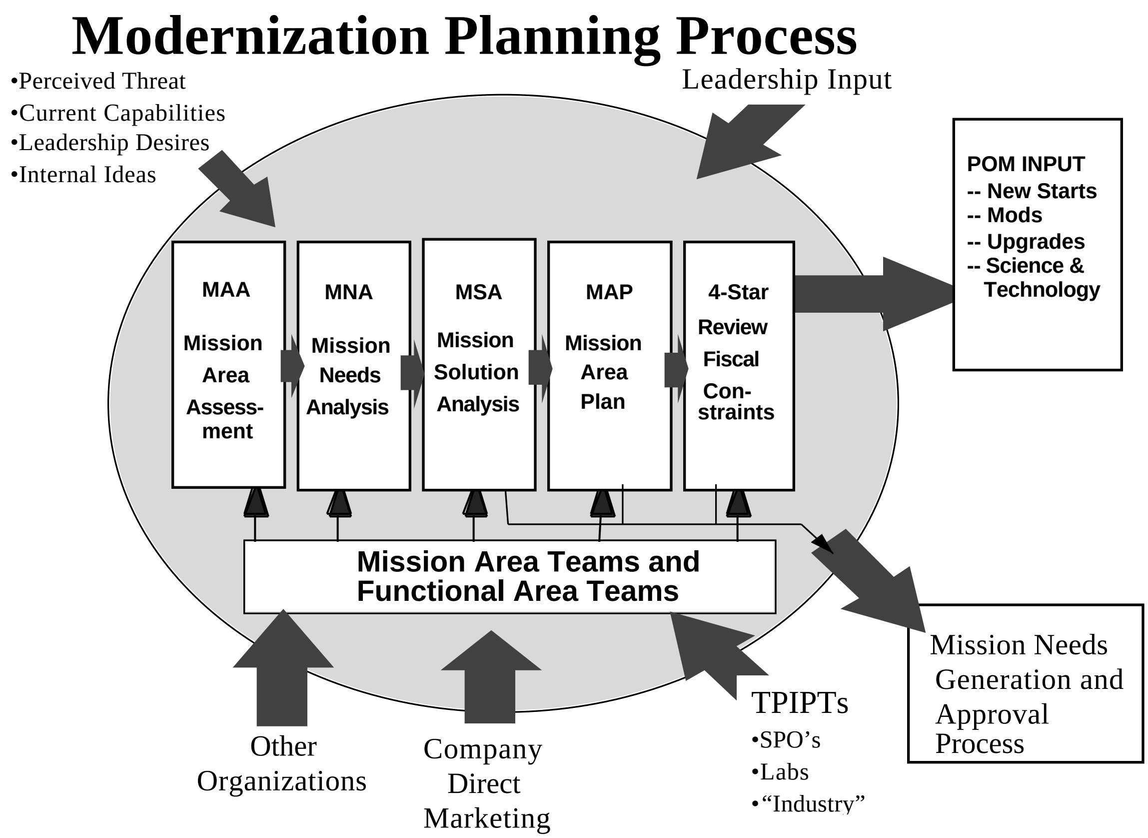


Figure 3-5: The Modernization Planning Process.

The Air Force modernization planning process is conducted by the major commands through a number of mission area teams and associated technical planning integrated product teams (TPIPTs). These plans project 25 years into the future and guide investments by the scientific, development, and contractor communities. The major commands lead the mission area teams, and the TPIPTs are managed by Air Force Materiel Command and the teams' associated product centers.

Thirty-eight mission area teams and functional area teams analyze capabilities in specific mission areas. One example is the Aerospace Control Mission Area Team, which examines offensive counter-air, defensive counter-air, and theater missile defense. The teams are supported by sub-teams associated with each weapon system, and by technical planning integrated product teams.

The TPIPTs include representatives from Program Offices, defense laboratories, and industry. These teams identify potential systems and concepts to meet needs set by the mission area teams. The TPIPTs also identify future technological needs that direct much Air Force laboratory research.

All these teams follow the “strategy-to-task” and the “task-to-need” processes to determine current capabilities, future deficiencies, and how best to overcome those deficiencies. After estimating potential enemy forces and capabilities for 25 years and projecting Air Force requirements, mission area assessments and needs analysis rely on the national military strategy to determine future needs. Mission solution analysis then determines the major commands’ preferred solutions for correcting deficiencies.

Mission Area Assessment (MAA) analyzes the ability of the unified commands and the major commands to undertake their assigned tasks and to fulfill a military contingency plan.

Mission Needs Analysis (MNA) then uses the task-to-need process to determine if existing forces can meet the current and future assigned missions. Identified mission needs are documented in a mission needs statement, which is used to make a Milestone 0 decision for developing any new or modified system.

Mission Solution Analysis (MSA) evaluates potential solutions and produces an “unconstrained set of preferred options.”[61] These options may include changes in operations tempo, readiness, training procedures and tactics, modification programs, force structure changes, new acquisitions, and science and technology programs.

Mission Area Plans (MAP) use the results of the mission area assessment and the mission needs analysis to “document the most cost effective means of correcting task deficiencies from among nonmaterial solutions, changes in force structure, system modification or upgrades, science and technology applications, and new acquisitions.”[62] The MAPs are roadmaps outlining the modernization plan for each weapon system in the mission area. Functional area plans are developed for cross-cutting areas such as communications.

The modernization planning process culminates with a four-star review by senior Air Force leaders, who approve the mission area and functional area plans. The potential solutions in the MAPs are then “racked and stacked” to determine which will be pursued.

[61] Briefing by HQ USAF/XOXP, AQ/XO Offsite. 1997.
[62] AFI 10-1401 *Modernization Planning Documentation*.

From the finalized MAPs, the major commands develop a prioritized list of new or modified systems. Requirements for new systems and modification of existing systems identified through this process will help determine how much funding each service receives, as well as when the process for establishing specific requirements begins and pre-acquisition planning occurs.

C.3. Leadership-Directed Projects

In a directed project, a senior leader begins a development effort not included in mission area plans. This frequently used top-down process contrasts with the bottom-up process used in modernization planning. Respondents to the surveys conducted as part of this research indicate that 42 percent of current Air Force projects were initiated as the result of leadership direction as opposed to formal modernization planning.[63]

Directed programs may result from a new technology, a highly visible deficiency, or the personal interest of a national or service leader. These directed programs will be incorporated into future mission-area plans for the major commands. A mission needs statement or operational requirement document used for this kind of program often references the senior leader's direction.

C.4. Mission Needs Process

A mission needs statement (MNS) documents the capability required to accomplish a certain operational task, as well as the inability to fulfill the need through training, tactics, or other non-materiel solutions. A validated MNS is required for a Milestone 0 decision, which allows for early studies of alternatives and the operational and cost implications of developing a new system.

Generating the Mission Needs Statement

The major commands write the mission needs statement based on the outcome of the mission needs analysis and mission solution analysis. A major command will also generate a mission needs statement at the direction of senior leaders. Major commands submit the mission needs statement to service headquarters for validation.

[63] The surveys and responses will be discussed in detail in Chapters 7-11.

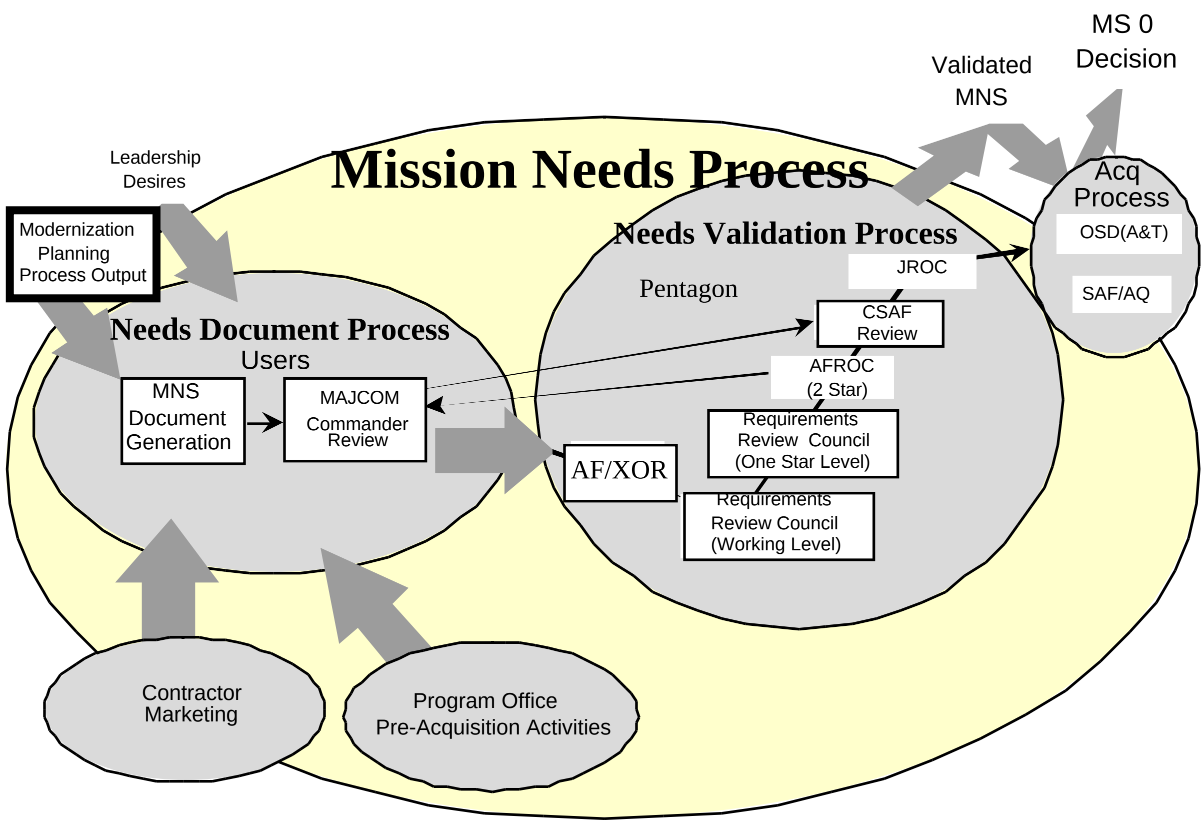


Figure 3-6: Mission Needs Statement Generation and Validation.

Validating the Mission Needs Statement

The validation process ensures that all operational needs are properly documented and agreed to by various functional groups before any development effort is begun.

A major command forwards a completed MNS to the Operational Requirements Division of the Pentagon, where it is assigned to a requirements action officer who shepherds it through the validation process. This officer submits the MNS to the working level of the Requirements Review Council, which consists of major and lieutenant colonel-level action officers from the functional groups. Following approval at the working level, the MNS is reviewed by the Requirements Review Council, which consists of colonel and brigadier general-level officers from various functional groups. Following council approval, the MNS is then submitted to the Air Force Requirements Oversight Council (AFROC), a two-star-general-level review by the deputy chiefs of staffs.

Once reviewed and approved by the AFROC, the MNS is returned to the major command for final review and signature by the commander. The final document is then sent to the Air Force Chief of Staff for approval and signature. Depending on the size of the potential project or the joint applicability, the MNS may also then be sent to the Joint Requirements Oversight Council (JROC) within the Joint Chiefs of Staff for further validation. The MNS is officially validated by the Air Force Chief of Staff or by the Joint Requirements Oversight Council.

The completed Mission Needs Statement is then sent to the Assistant Secretary of the Air Force for Acquisition, or to the Under Secretary of Defense for Acquisition and Technology. That person makes the Milestone 0 decision to authorize studies of how to best meet the identified need and to define the operational requirement for the new or modified system.

D. Generating and Validating Requirements

Requirements document the capabilities a new system must have to succeed. In practice, there is significant overlap between the process of establishing requirements and the planning activities described earlier. The requirements community consists of groups at the major command headquarters and the Pentagon. Each major command has a director for requirements who is responsible for evaluating current capabilities, identifying deficiencies, and defining the requirements for new systems in operational requirements documents. Within Air Force headquarters, the Operational Requirements Division (HQ AF/XOR) reviews the documents, coordinates them with other Pentagon organizations, and maintains the library of validated documents. Depending on the project's size and scope or joint service applicability, the document must be validated by the Air Force Chief of Staff, the Air Force Requirements Oversight Council (AFROC) or the Joint Requirements Oversight Council (JROC).

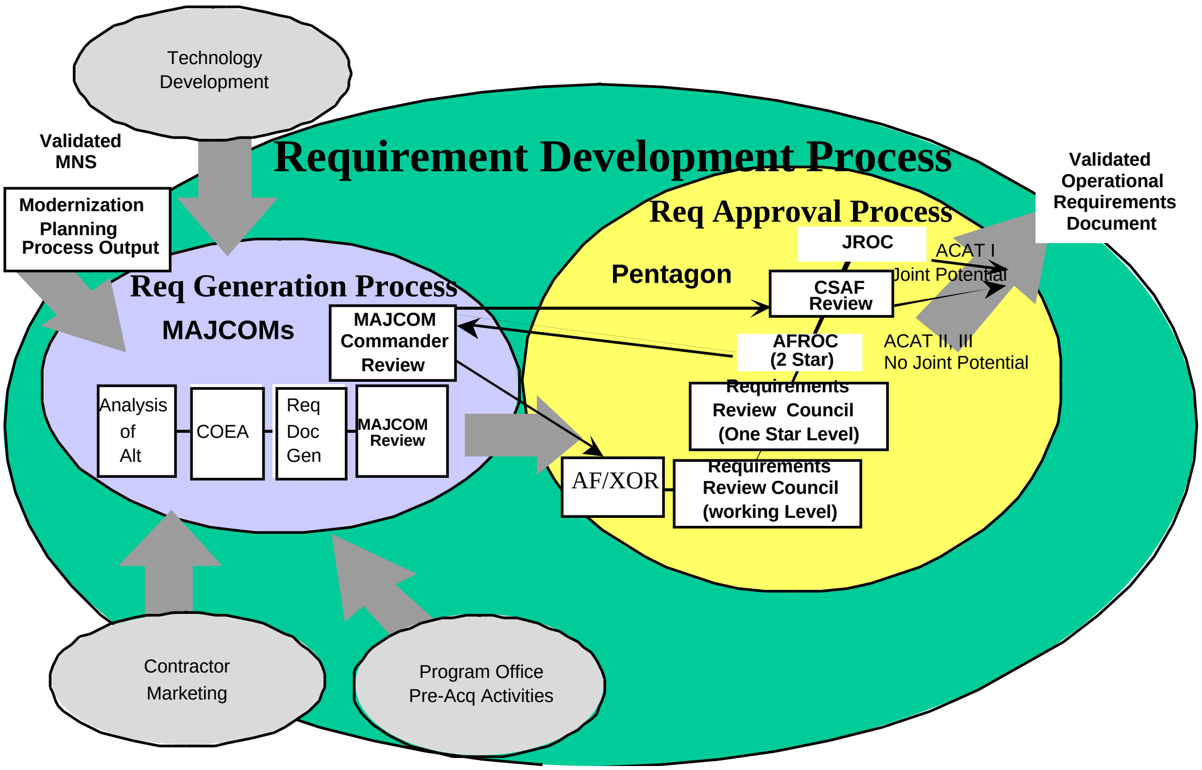


Figure 3-7: The Process for Generating and Approving Requirements.

D.1. Generating Requirements

Operational deficiencies and solutions are turned into a set of requirements that form the basis of a development effort. When complete, the systems will be tested to determine how well they meet the requirements. The major commands specify requirements by evaluating alternatives, performing Cost and Operational Effectiveness Analyses (COEAs), determining the operating parameters for a specific system, and developing the operational requirements document.

The general characteristics of the desired system are defined by various outputs from modernization planning--often the mission solution analysis--or by directions from senior leadership. The process focuses on how to fulfill the need with the selected system, how the system should work, and what the specific operating characteristics should be. For example, if service leaders have selected a new aircraft to fill a specific need, the requirements will define what the characteristics of the new aircraft must be to fill the need.

The primary steps involved in generating requirements are analyzing alternatives, analyzing cost and operational effectiveness, and generating the operational requirements document.

Analysis of alternatives (AoA) identifies alternative methods of meeting the operational requirements and resolving mission deficiencies following a Milestone 0 decision. The results of these concept studies are used to prepare the cost and operational effectiveness analysis.

Cost and Operational Effectiveness Analysis (COEA) is used to assist decision makers in selecting the most cost-effective method to fulfill a mission need. The COEA process compares several solutions on the basis of cost and operational effectiveness and documents the rationale for choosing the preferred solution. COEAs are required for all major defense acquisition programs. Formal COEAs are not required and are not typically performed for smaller programs (ACAT II and III).

The Operational Requirements Document (ORD) describes the concept of operations and the specific performance measures—both the minimum and threshold (desired) levels that the new system is to fulfill. If the system cannot meet the threshold parameters, senior leaders must decide whether to continue the project. These key performance parameters are included in the acquisition program baseline and are reviewed as part of the milestone decision points. No acquisition effort can proceed through Milestone I without a validated operational requirements document.

The ORD is updated before full-scale development (Milestone II) and production (Milestone III) to include additional information as the system is further defined. A requirements correlation matrix tracks changes in the requirements over time and documents the reasons for the changes. These and other analyses form the basis for the subsequent acquisition efforts for the system.

D.2. Approving the Requirements

Leaders in the major commands review the ORD, which is then submitted to headquarters and the Requirements Review Council and follows a path similar to that of the Mission Needs Statements. Validating the requirements can take several months to several years, depending on the contentiousness of the issues and the desires of the leadership.

A validated ORD is considered the definitive statement of users’ requirements and becomes the technical input into the acquisition process. Once the requirements are established and validated through this process, they cannot be changed without a new review. A validated ORD is required to authorize the start of a formal acquisition process.

E. Allocating Resources

Following the modernization planning process and concurrent with the requirements process, any acquisition effort must successfully negotiate and obtain funding, equipment, and personnel through the resource allocation process. This process is used to develop Air Force and DoD budgets for all activities, and includes the major commands, the Pentagon, DoD, the administration, and Congress. Several different functions are involved, including programming, which authorizes all activities; budgeting, which projects costs and develops annual budget requests; and resource distribution, which disburses and tracks funds once Congress appropriates them. Approved and scheduled funding for development and production is required for the Milestone I decision that authorizes the start of a project.

Resource Allocation Process and PPBS

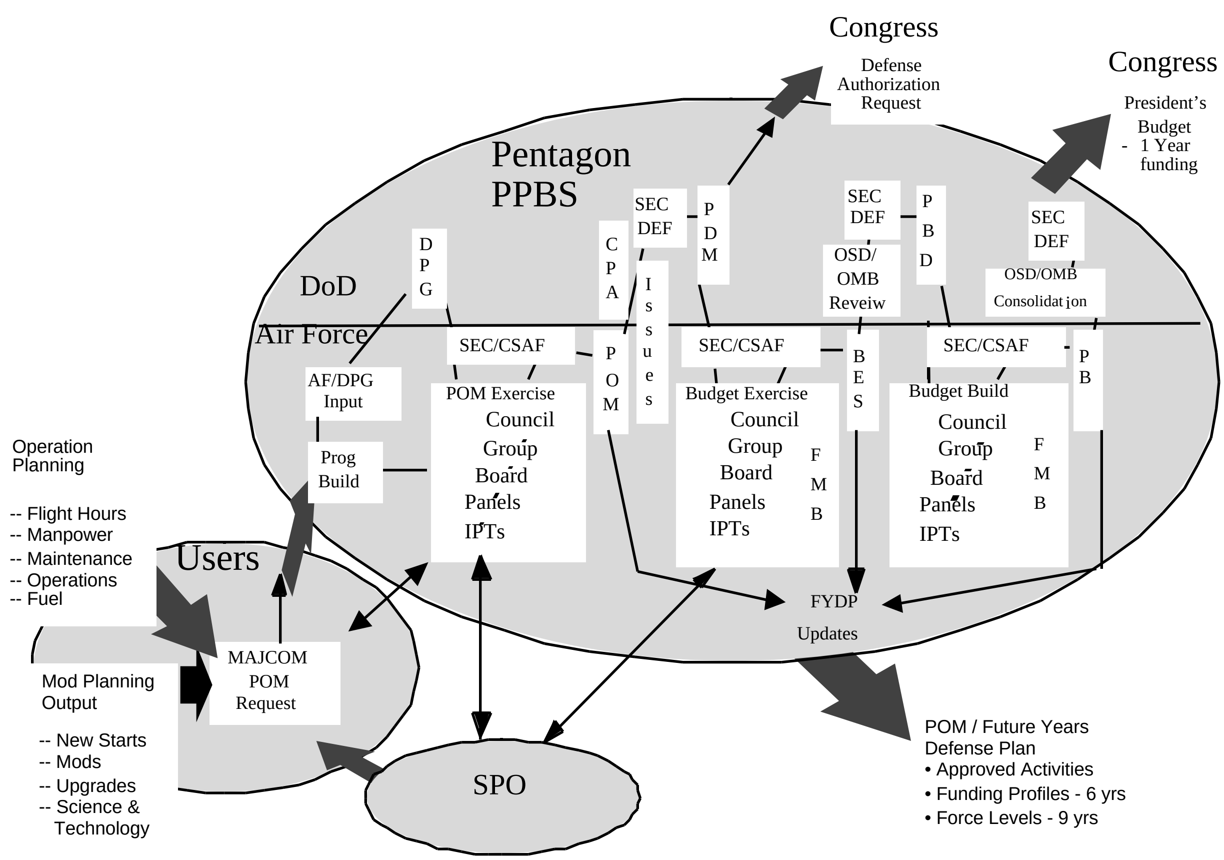


Figure 3-8: Resource Allocation Processes.

Resource allocation and the Pentagon's planning, programming, and budgeting system (PPBS) include multiple steps over a two-year period. Each major command develops a Program Objective Memorandum (POM), which the Pentagon then uses to develop a POM for each service and the total annual request included in the President's Budget. Once Congress has allocated the money, funds are distributed in accordance with the POM as defined by defense appropriations law.

E.1. Developing the Program Objective Memorandum

Every year each major command projects the resources required to accomplish the missions it must fulfill and to procure the new systems it desires. This information is captured in the Program Objective Memorandum (POM), which covers activities ranging from purchasing fuel and maintaining systems, to developing new products, to training and deploying troops and sustaining existing operations. The POM covers all funding projections for six years and force structure for nine years, and is submitted two years before the first fiscal year to which it pertains. Headquarters for the major command typically develops this document with input from each group within the command. After internal reviews, the commander approves the request and it is forwarded to service headquarters. This document then becomes the initial input to the Pentagon's planning, programming, and budgeting system.

E.2. The Pentagon's Planning, Programming, and Budgeting System

The PPBS is a multi-step annual process used to authorize activities, allocate resources, and develop the service and DoD budgets. Defense Secretary Robert MacNamara began the PPBS system during the 1960s in an attempt to bring focus, coordination, and control to the defense planning and budgeting processes.

Each activity the service undertakes must be covered by a program element, which allocates all funds and resources. The lowest level in the PPBS system, the program element, can represent a single weapon system undergoing development or an ongoing military operation. A program element monitor (PEM) is the official spokesperson for that activity within the Pentagon.

Planning and Programming

The planning and programming process develops and integrates the Program Objective Memorandum and maintains the Future Year Defense Plan (FYDP). These documents authorize the services to both carry out and budget each specific activity. The director of program and evaluation under the Air Force Chief of Staff oversees the planning and programming process.[64]

[64] HQ USAF/PE was recently placed under HQ USAF/XO to create HQ USAF/XOP.

The planning function within the Pentagon begins with the submission of the POMs from the major commands. These inputs assist the Chiefs of Staff and the Service Secretaries in advocating their positions and developing Defense Planning Guidance (DPG). The latter is a high-level document that sets the stage for apportioning resources among the services and within various mission areas. After the DPG is issued, the major commands update their POMs based on the expected allocations among services and mission areas.

The programming function takes the updated POMs and develops a consolidated program outline of all Air Force activities. This program is then worked through an elaborate process to ensure that it fits within the expected budget and program guidelines directed by Office of the Secretary of Defense, and that it meets the requirements of the senior Air Force leadership. The elaborate process used to make these decisions and tradeoffs is known as the enhanced Air Force corporate process, and includes over 70 separate weapon teams, 10 mission area panels, and 3 additional levels of review; before it is submitted and approved by the Chief of Staff and the Secretary of the Air Force. This entire process involves the participation of a significant number of people in the Pentagon.

The secretary of defense then approves a program decision memorandum, which outlines the proposed programs for the services. This memorandum forms the basis for the Future Years Defense Program (FYDP), which outlines the path for the military services over the next six years. The program decision memorandum is then submitted to committees in Congress for their authorization.

The Enhanced Air Force Corporate Process

The enhanced Air Force corporate process includes five levels of review within the Pentagon prior to the final review by the Chief of Staff and the Secretary of the Air Force. It is intended to provide the senior leadership with the “corporate position while retaining the responsibilities of the functional organizations.” In other words, the “corporate position” is a negotiated result and compromise solution on the funding levels for various Air Force activities between the organizations and personalities represented within the various panels, board, groups, and council.

The different levels of review are described below and depicted in Figure 3-9. In 1997, development and procurement activities represented 32 percent of the total Air Force budget.

Integrated process teams (IPT) are staffed by the various program element monitors and action offices associated with a weapon system. The IPT is the single point of contact for the major commands to specific programs. There are roughly 70 separate weapon system IPTs.

Mission and mission support panels serve as the Air Force "centers of expertise" and represent the first level of corporate review within each of 10 mission areas. While retaining a corporate or Air Force-wide perspective, the panels must still play the role of advocate for a particular project within the corporate process.

The Air Force Group undertakes the first integrated Air Force-wide review and consists of 23 core members and 7 members representing the functional areas of the Air Force. During the POM process, this group is empowered with "off-the-table" decision authority (they can say no to a decision, but not yes) as the AF Group brings ideas forward to the Air Force Board.

The Air Force Board is a two-star-level review staffed by the deputies of senior leaders in each major functional area. The board now consists of 23 core functional areas and 7 other members.

The Air Force Council, a three-and-four-star level review, consists of senior leaders from the various functional areas and major commands. The council provides recommendations that are coordinated at senior levels across the Air Force and forwarded to the Air Force Chief of Staff and the Secretary of the Air Force.

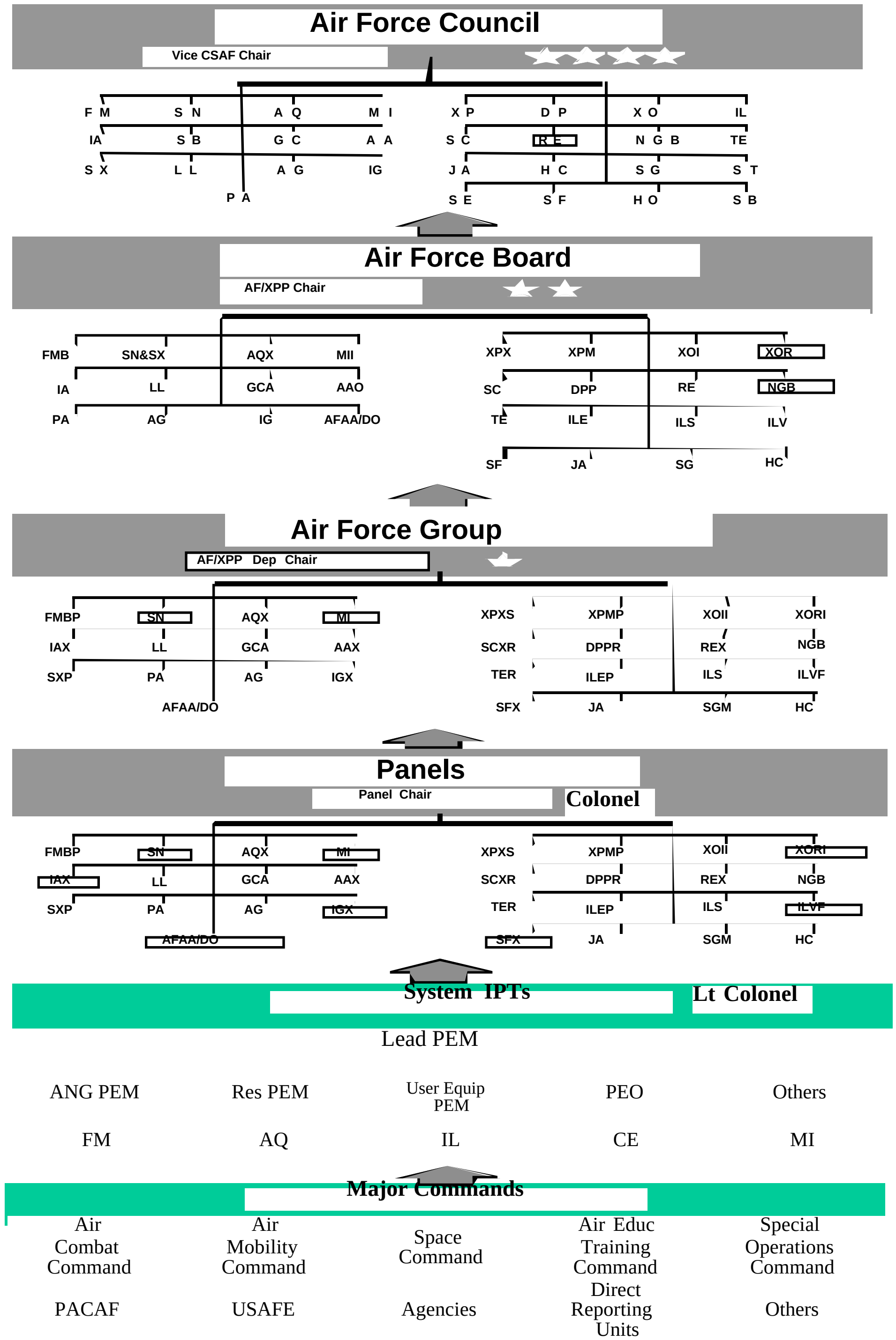


Figure 3-9: The Enhanced Air Force Corporate Review Process.[65]

[65] Developed from USAF Document "The Planning, Programming, and Budgeting System & The Air Force Corporate Structure (AFCS) Primer, 9th Edition." AF/XPPE. May 1998.

Budgeting

The Air Force budget process is organized and controlled primarily by the Assistant Secretary of the Air Force for Financial Management, and more particularly by the budget division. The annual budget is developed based on the results of the Program Objective Memorandum. The budgeting process develops more accurate estimates of the costs of executing approved activities by updating previous estimates using current prices, inflation estimates, and economic forecasts. The budgeting process also separates the required funds into categories used to submit the overall Air Force budget estimate and compose the President's Budget to Congress.

Based on these estimates and changes as directed by guidance from the Secretary of Defense, the Air Force Corporate Process Structure reworks the Air Force program to create the budget estimate submission (BES). The BES represents the Air Force input into the annual DoD budget request. Following a review by the Office of the Secretary of Defense and the Office of Management and Budget, the Secretary of Defense issues a President's Budget Decision (PBD). The services again adjust their program to comply with the PBD and finalize the Air Force budget. The President's Budget is then submitted to Congress for approval and enactment.

Once the budget is passed by Congress and signed by the president, the budget and comptroller communities distribute funding and track expenditures to ensure that no money is spent that is not allocated and appropriated for a specific project.

The outcomes of this entire process--Program Objective Memorandum and the Future Years Defense Program -- are inputs into the acquisition processes and critical to a product development effort. With the added expectation of an approved Operational Requirements Document, the steps typically associated with the acquisition processes begin. Participants in the acquisition processes take the users' requirements and expected resources and develop an acquisition plan, select a contractor, and develop the product and the manufacturing process.

F. Acquisition Planning and Approval

In the acquisition approval and milestone decision processes, the service headquarters and service acquisition executive review the proposed plans and decide if the project can proceed to the next stage.

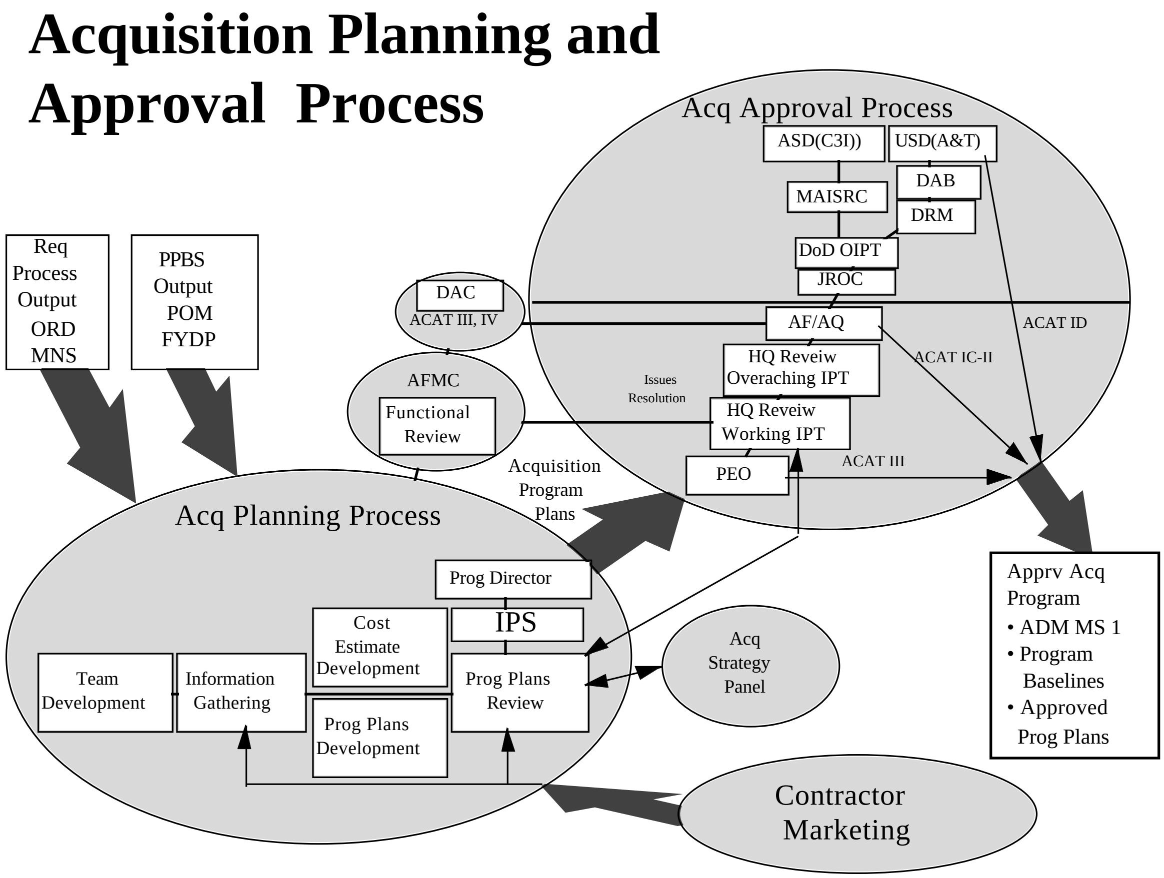


Figure 3-10: Acquisition Planning and Approval Processes

F.1. Acquisition Planning

This process develops plans based on the users' Operational Requirements Document. The major acquisition planning steps include developing a team, collecting information, creating program plans, projecting costs, and developing an acquisition strategy. The major products are acquisition plans, cost estimates, proposed project schedules, and a proposed acquisition program baseline that outlines the project's cost, schedule, and performance objectives.

The planning effort is accomplished by a newly formed Program Office specific to the project, or by a team within an existing Program Office. The Program Office typically surveys potential contractors to understand abilities and technologies available to the project. From this information, the Program Office develops a series of plans that outline how, when, and at what cost the project can proceed. The plans typically include an acquisition plan, a source selection plan, and system engineering plans including a work breakdown structure, a master plan and a master schedule. The plans also include an integrated logistics support plan; a test and evaluation master plan; a human system integration plan; and a threat assessment report. These plans and reports cover the entire expected life of the program, not just the development effort. During this phase, the Program Office develops detailed cost estimates showing that the plans are affordable within the expected resources, as required for a Milestone I decision. The reports officially required for a Milestone I decision for major defense acquisition programs are shown in Table 3-1.

Acquisition Strategy Report	Description of Data Requirements
Acquisition Program Baseline	Exit Criteria
Affordability Assessment	Independent Estimate of Life-Cycle Costs
Future Years Defense Program Funding Profile	Operational Requirements Document
Analysis of Alternatives	Program Office Life-Cycle Cost Estimate
Component Cost Analysis	System Threat Assessment Report
Cost Analysis Requirements Description	Test and Evaluation Master Plan

Table 3-1: Information Required for a Milestone I Decision for Major Defense Acquisition Programs

When the plans are complete, the Program Office holds an acquisition strategy review with a panel of outside experts and consolidates the results into an integrated program summary. This summary is signed by the program director and forwarded to the Pentagon for review and approval.

F.2. Acquisition Approval

Milestone approval is the formal process used to review projects and authorize them to proceed to the next acquisition phase. Formal milestone decisions are required by Defense Acquisition Directive 5000.1, which gives the Defense Acquisition Executive and Service Acquisition Executives the milestone decision authority for major programs. For smaller programs the product center commanders, also known as Defense Acquisition Commanders (DACs), have milestone decision authority. Milestone decisions are intended to ensure that all essential issues are addressed prior to approval for the program to proceed. After a Milestone I decision initiates a formal acquisition program, a Milestone II decision authorizes full-scale development, and a Milestone III decision authorizes full-rate production.

Before a milestone decision, a project must pass through a series of Pentagon reviews. Each major organization involved with any aspect of the development program is represented on two respective teams: the Working-Level Integrated Product Team (WIPT), and the Overarching Integrated Product Team (OIPT). The people and organizations involved with these teams overlap significantly with the earlier integrated product teams that allocated resources.

These committees are intended to resolve all issues before submitting the entire package to the Air Force System Acquisition Review Council and the Assistant Secretary of the Air Force for Acquisition for final approval. The largest programs are reviewed in the Office of the Secretary of Defense, by the Joint Requirements Oversight Council, the DoD-level Overarching IPT, and the Defense Acquisition Board prior to approval by the Under Secretary of Defense for Acquisition and Technology.

A Milestone I decision yields a signed acquisition decision memorandum authorizing a formal acquisition project and a baseline specifying cost, schedule, and performance. Deviations from the approved requirements or the acquisition strategy require similar approval from the milestone decision authority. An approved Milestone I decision allows the program office to start the contracting processes.

G. Contracting

Contracting is a critical part of the development process. The basic contracting process is dictated by federal acquisition regulations and applies across all federal agencies. Its two primary purposes are to select a contractor, and to agree on terms and conditions for the contract. Contracting can be separated into three periods: planning for release of the request for proposal, the period in which the contractors develop their proposals and selection of a contractor and award of a contract by the Program Office.

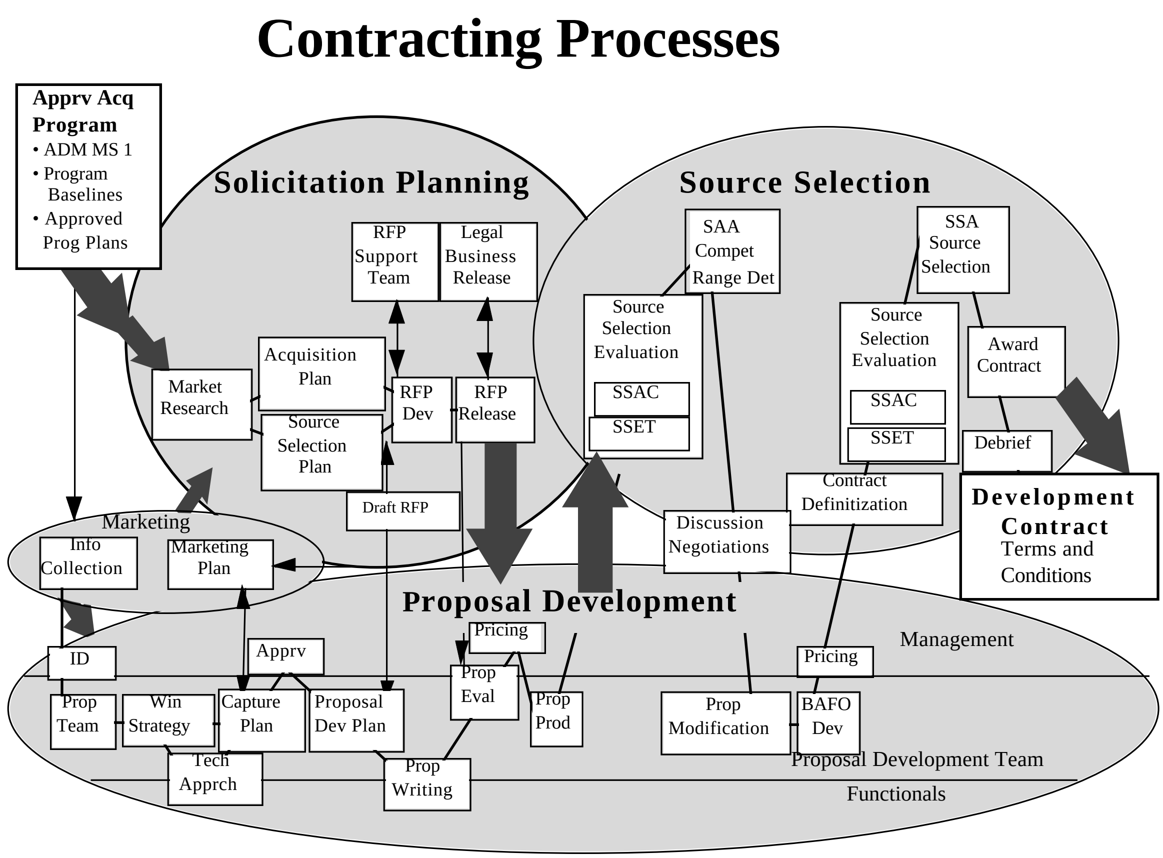


Figure 3-11: The Contracting Process.

G.1. Solicitation Planning

The many-step process of planning the solicitation overlaps significantly and is often indistinguishable from some of the early acquisition planning processes. One early step is market research to identify potential contractors. The solicitation planning stage also includes developing the acquisition plan, which schedules the contracting steps and specifies the requirements for the solicitation.

This phase also spells out the process to be used to select the winning contractor, including the evaluation criteria and the specific weights assigned to each. The criteria and the relative weighting are provided to the contractors as part of the request for proposals. The source selection criteria cannot be changed after the request for proposals is issued, to prevent manipulation.

A major part of solicitation planning is developing the formal document that tells contractors what the government requires and how the contractors are to respond. Contractors are typically asked to comment on the RFP while it is in draft, to identify particularly onerous or costly requirements.

The first part of the RFP typically includes a model contract and the procedures and ground rules for selection. The second part describes the procedures and ground rules to be followed in the proposal, the basis for selection, and the specific information needed to make the selection. This section usually asks for technical, management, and price or cost proposals detailing various aspects of a contractor's proposed development effort. All Air Force RFPs are reviewed by the centralized RFP support team to ensure that the requests do not tell contractors how to do things but instead simply state the objectives.

As part of solicitation planning, the Program Office develops detailed cost estimates for the proposed contracts it is requesting. This helps ensure that the Program Office is not requesting more development effort than it can afford, and is used to select and negotiate with the contractors.

Each step in the solicitation planning process undergoes legal review to ensure that it adheres to appropriate laws and regulations. The final review is a business release that allows the RFP to be issued. The solicitation planning phase ends when the Program Office releases the request for proposals, after which no informal discussion between industry and the Program Office is allowed, to prevent favoritism. The next process entails development by the contractors of a proposal.

G.2. Proposal Development

For defense contractors, winning the source selection process is the most important aspect of their business. Because a single contractor usually develops, produces, and maintains defense systems, not being selected at any point in the process will often eliminate a company from the entire market. Defense contractors therefore place great emphasis on their ability to develop proposals and their responsiveness to customers. The following description is based on a number of industry guidelines for developing proposals, interviews with industry participants in the Lean Aircraft Initiative, and a course run by the Educational Service Institute that teaches government personnel source selection procedures.[66]

Proposal development and marketing activities begin long before release of the RFP—and indeed even before the Program Office establishes a project. Companies often propose solutions to needs directly to users, the Pentagon, and the Program Offices in an attempt to initiate contracts they can easily win. One primary function of companies' marketing divisions is to identify upcoming projects that fit within the company's product line. Marketing divisions seek information such as the budget for potential projects, their sponsors and their interests and concerns, and the concerns of the Program Office leaders. One objective is to slant specifications and source selection criteria toward the company's approach. Marketing divisions also identify potential competitors, their likely approaches, and their level of interest in the project. Early market research ensures that a company has adequate time and the necessary information to develop an effective proposal, as companies often submit their proposals right after the legal minimum of 30 days following release of the RFP.

When a company identifies a project that the firm stands a significant chance of winning, it establishes a proposal development team. This initial team evaluates the information from marketing and develops a strategy for winning the contract. After consulting with engineering groups, the team selects the best technical approach and develops a "capture plan" detailing and coordinating the company's efforts to win the contract. The capture plan includes a marketing plan and a proposal development plan. The marketing plan ensures that the Program Office is fully informed--and hopefully convinced--of the benefits of the company's specific approach. Marketing efforts also ensure that the proposal addresses Program Office concerns, and the contractor's internal proposal evaluation ensures that the proposal has met all RFP requirements and provides specific answers to fulfill the criteria. The capture plan is presented to senior management for their approval.

According to industry proposal training material, "the proposal is primarily a selling tool designed to stress customer objectives and customer benefits, while stating the customer's problem

---

[66] The description is obtained primarily from two company proposal development guides for which documentation was obtained. The companies requested not to be identified. Interviews with other industry representatives supported the

in his terms and presenting the solution in a clear and straight forward manner." The guidelines stress that "the proposal is not the place to tell the government it is wrong. . . [That] is not a winning strategy." Instead, a company often portrays alternative approaches by other firms as inferior, to make the strongest case for its approach. Many companies also create groups that solely prepare or assist in preparing proposals, led by a proposal manager and a proposal development specialist. The proposal manager often becomes the program manager if the company wins the contract.

Proposals are typically written in sections, each targeted to different evaluators on the source selection team. Those elements, which typically include an executive summary, the technical approach, the program plan, and the management plan, are expected to stand alone. The program plan and the technical approach require creation of a work breakdown structure and the systems engineering management plan.

Companies often have the option of submitting an alternative proposal that presents a program different from the one the government has requested. Such proposals may not meet all the government's requirements but may showcase an innovative approach to meeting users' needs. However, according to the Aeronautical Systems Center Pre-Award Support Office (a group that helps many program offices develop requests for proposals and run source selections) contractors take this route only rarely.

After drafting and evaluating the proposal, company management sets the price it will bid. Managers base this decision on cost estimates developed by the proposal team, evaluation of potential competitors' strategies, and the importance of winning the project. Once the final price has been set, final proposal production occurs. Submission of contractors' proposals begins the source selection process.

G.3. Source Selection

Before beginning source selection, a Program Office writes a plan that specifically describes the process to be used to evaluate the proposals. The Source Selection Authority approves this plan before release of the RFP.

The selection process typically includes a Source Selection Evaluation Board (SSEB) composed of several panels that evaluate different aspects of each proposal; a Source Selection

---

statements contained in the guides. The process described is similar to the process outlined in an Educational Services Institute course on source selections.

Advisory Council (SSAC); and a Source Selection Authority (SSA). The SSEB is solely responsible for evaluating the proposals against the set standards--it does not evaluate different proposals against each other. The Source Selection Advisory Council, composed of senior military and government personnel, reviews the SSEB finding, compares the proposals, and considers contractors' past performance. This committee makes a recommendation to the Source Selection Authority, which then selects the competing contractors with which DoD will negotiate. The committee can pursue a contract without negotiations by choosing one of the original proposals unmodified.

Negotiations further refine and clarify the contractors' proposals to better meet the expectations and concerns of the Program Office. Care must be taken to provide all competing contractors with similar information but not to share proprietary information. Companies then modify their proposals and develop their "best and final offer." During this period a proposed formal contract between the Program Office and the contractor, specifying which aspects will be made legally binding and under what conditions, is written and prepared.

Using the contractor's best offer and the finalized contract, the Source Selection Authority can choose either the best-value proposal or the lowest-cost technically acceptable proposal. Decision makers may ignore the scores, re-score the proposals, or declare differences insignificant, but the selection is susceptible to protest and judicial review. While protests occur frequently, few are upheld. Of the 47 protests in 1995, for example, only 2 were upheld.[67] The Air Force often goes to great lengths and expense to ensure that the source selection is "fire-proof" and can withstand a protest.

Following the source selection decision, the Program Office can award the contract and development can begin.

H. Developing the Product and Process

Development of the actual product and the process used to make it is conducted primarily by the contractors. The contractors' development activities are overseen by the Program Office, to identify problems early on. The Pentagon oversees the activities of the Program Offices and the contractors, to alert senior leaders to problems. A process is also available to modify the contract and requirements to adapt to unforeseen events.

---

[67] Lt Gen Franklin's Briefing to Industry Day at Electronic Systems Center. Hanscom AFB MA. March 1996.

H.1. Product and Process Development

Contractors themselves can determine how best to develop a product and the process used to make it, as long as they remain within the bounds of the contract. Contract specifications can be extensive if they include the system engineering management plan and work breakdown structure. A company's development efforts typically follow standard system engineering approaches, with a series of internal reviews, tests, and audits as a design matures. Many of the company's activities are driven by program oversight requirements.

Contractors receive progress payments throughout development. The amount is determined by the cost work breakdown structure and its packages as described in the contract and as measured through the company's cost/schedule control system (C/SCS), which the companies keep in accordance with DoD accounting requirements. Contractors' requests for payment are certified by the Program Office and sent to the Defense Finance and Accounting Service.

H.2. Development Oversight

The development oversight process involves two distinct levels: program oversight of the defense contractor, and Pentagon oversight of the Program Office. Each is intended to ensure that the proper actions are taken, and that the development of the desired product is proceeding within the technical and cost parameters.

Program Office Oversight of the Contractor

To ensure progress towards completing the design, and a design that will meet the requirements, the Program Office conducts periodic reviews of both the design and its financial performance. These reviews offer insight into the technical aspects of the development process and allow for early identification of potential problems. Progress is measured against the company's planned or contracted schedule.

The Program Office performs financial oversight through the cost/schedule control system, which formalizes periodic reports indicating the funds spent by the contractor and the amount of work accomplished. From these reports the Program Offices can determine the budgeted cost of the work performed, the actual cost of the work performed, the budgeted cost of the work scheduled, and the estimated cost at completion. These are used to determine if the contractor is meeting the schedule and cost estimates established in the contract.

Pentagon Oversight of the Program Offices

Pentagon oversight of the Program Office and the contractor is more limited than Program Office oversight of contractors. Pentagon oversight is often dependent on Program Office reporting. Quarterly reports are due from all major defense acquisition programs as part of the defense acquisition executive summary (DAES), completed by the Office of the Secretary of Defense. Smaller programs are subject to reviews by their respective program executive officer or product center commander. (Each Development Center and Program Executive Office also conducts an annual portfolio review with the senior acquisition executive to review the breadth of projects.)

Test results and completion of major milestones on schedule indicate that the technical aspects of a program are likely under control. Missed milestones or failed tests indicate that there may be problems and often provoke greater Pentagon scrutiny and oversight. A final operational test and evaluation (OT&E) follows completion of the development effort and precedes full-rate production. OT&E tests the system against the operational requirements document and provides an independent assessment of the development effort.

H.3. Change

During development effort requirements may change, the contract may change, and annual funding may change. These changes may be directed by the Pentagon or the users, or they may come from the contractors. Changing established program plans is difficult for both DoD and contractors.

Revisions in the annual projected budget are one of the major sources of change in defense programs. When the allocated budget is changed, the Program Offices must adapt to the often lower level of funds, and the contract must often be re-negotiated. Additional requirements based on changing circumstances, or the availability of newer technology, may also change users' desired capabilities.

Bottom-up changes are often the result of problems within a development effort. The inability to meet cost, schedule, or technical performance requirements often force a contractor and a program office to suspend requirements, increase funding, or to delay the product. These changes often require a significant amount of effort to obtain agreement from the Pentagon organizations that must review and approve them. Such changes must follow a similar path as the original approval process, as must requests for additional funding, which must also compete with other projects. What's more, changes to the acquisition program baseline require a similar level of review as the original milestone decision process. Surmounting these hurdles requires considerable effort and attracts greater scrutiny to a project.

Chapter Summary

The Air Force product development process described is a complicated and elaborate process. The major players in the development process include the major commands, the various Pentagon organizations, the program offices, and the defense contractors. The earliest development processes includes many processes from the modernization planning process, to the mission needs process, to the requirements generation and approval processes. The planning, programming, and budgeting system as implemented by the Air Force through its corporate process is an very elaborate process encompassing 6 layers of review multiple times per year. The acquisition processes include the acquisition planning and approval process, the contracting process and the contractor oversight process. Many of the processes involve multiple levels of reviews within the Pentagon and major commands. Each of these processes is currently required to develop a project. While the Air Force product development process may be slightly more complicated than those of the other services, the basic steps are similar. How the structure of this complicated process affects the development time of individual acquisition efforts and how it affects the development process as a whole is the subject of this investigation.

Part 2

Research into the Process Used to Develop Project Schedules

Part 2: Overview

The areas associated with long cycle times in Air Force development projects are too numerous to study within the time and resources available. Initial interviews and preliminary research indicated that the process used to develop project schedules was likely to play a significant role in determining the time to develop new products. Thus, I chose to focus the research on *the process used to develop the project schedules and its impact on the resulting development time*.

Chapter 4 provides the justification for focusing on the process used to develop project schedules. It also describes previous research on the topic and the limited available data. Chapter 5 describes the selection of the research approach and identifies a multilevel survey as the appropriate method to collect the required data. Chapter 6 describes the Pentagon, Program Office, and contractor surveys used to collect the necessary data on development of the initial project schedules, and discusses the characteristics of the 317 projects surveyed. Chapter 7 describes the process used to analyze and present the data.

Chapter 4

Narrowing the Research Focus to the Schedule Development Process and Its Impacts

The primary goal of this study is to identify the key factors that influence product development time, and that keep the military from making reductions similar to those achieved with commercial products. This chapter provides the rationale used to narrow the research focus from acquisition response time to product development time, and then to the programmatic aspects of a project. To do so, the chapter describes the conceptual framework used to separate different aspects of a project that may affect development time.

This chapter includes initial observations of the schedule development process based on preliminary research, describes the relationship between the project schedule and development time, and poses the series of initial questions that guided the research. The chapter then summarizes previous research associated with project development schedules. The overall objective is to identify key factors or processes that influence the actual time from decision to proceed to delivery of the first production item for military products.

A. Narrowing the Research Focus from Acquisition Response Time

Narrowing the research focus to the process used to develop the project schedule entailed several intermediate steps. First, the focus was narrowed to look at product development time, then to look at the programmatic aspects associated with the planning of a project, and then to the process used to develop the project schedule. The rationale for the focus at each level is discussed below.

A.1. Narrowing the Focus to Development Time

As discussed in Chapter 1, acquisition response time is a measure of the ability of the acquisition system as a whole to respond to the needs of warfighters. Acquisition response time includes periods--recognition, decision, development, and production--involving significantly different types of activities and groups, as described in Chapter 3. Combining the different periods would obscure important factors driving acquisition response time, but addressing all the periods would have been too broad a scope. I decided to focus on one of the periods in detail.

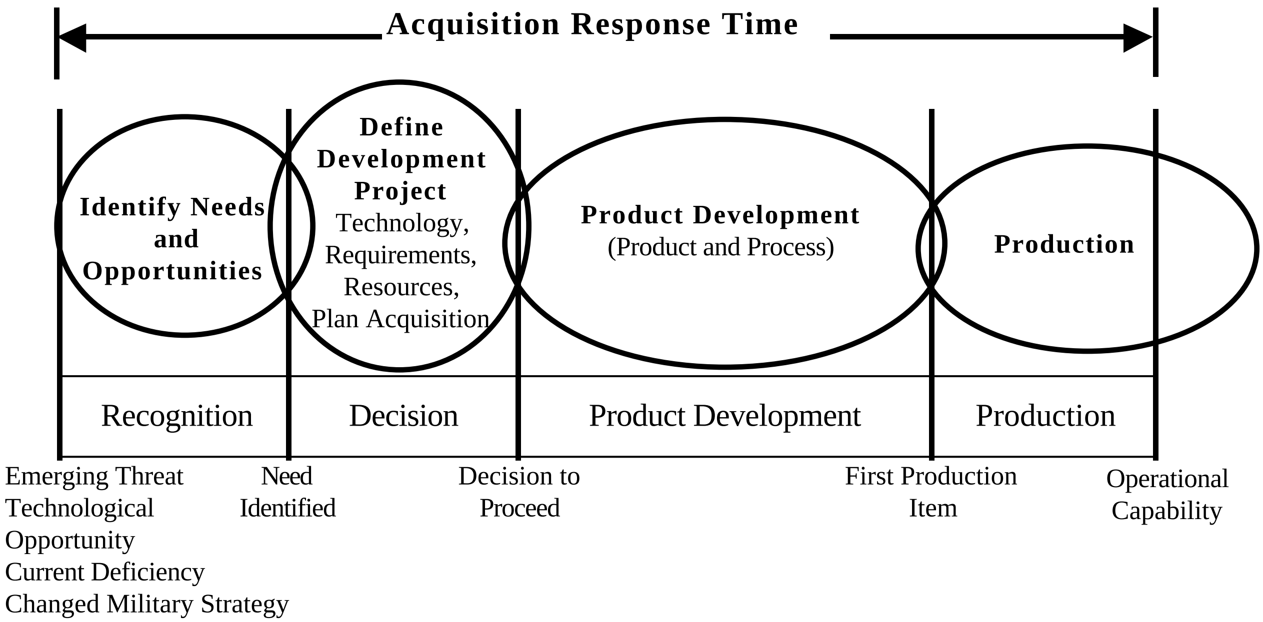


Figure 4-1: Components of Acquisition Response Time.

Product development time appears to be the largest component of acquisition response time. Development time starts at project initiation in the commercial case or at a Milestone I or equivalent decision for a military system, and ends with delivery of the first production item. New major defense acquisition programs completed between 1990 and 1994 averaged 132 months--11 years--from project initiation to first operational capability.[68] Of those 132 months, 108 months were spent on the product development phase, from the decision to proceed until delivery of the first production item. Development time for major defense products has continued to increase over the last 20 years.

---

[68] See Figure 1-7.

Average times for product development alone are projected to soon approach 11 years. Thus I decided that for this research to effectively reduce the time required to field new military systems, it must focus on product development time. However, the time required for recognition, decision, and production is equally important in contributing to acquisition response time. These areas are left for follow-on research.

A.2. Narrowing the Research within Product Development

Many elements contributing to development time could be studied. To identify which areas were likely to have a large impact on development time, preliminary interviews, analysis of available data, and literature reviews were conducted in both commercial and military arenas. This initial research into the causes of long cycle times led to a framework for categorizing various aspects of a military project, and then to one area -- the programmatic aspects -- for further research.

To provide a contextual framework for product development efforts, three different areas affecting development time were defined: programmatic, organizational, and engineering. Each of these areas can be described at two levels: the company level, affecting a portfolio of projects; and the project level, affecting a particular project.

Programmatic aspects at the project level include defining the project and the product concept, determining available resources, setting the project schedule, and establishing the project's technical objectives. Other programmatic aspects include the acquisition strategies used to develop the project, the acceptable risk associated with the project, and the criteria to make cost, schedule, and performance tradeoffs within the project.

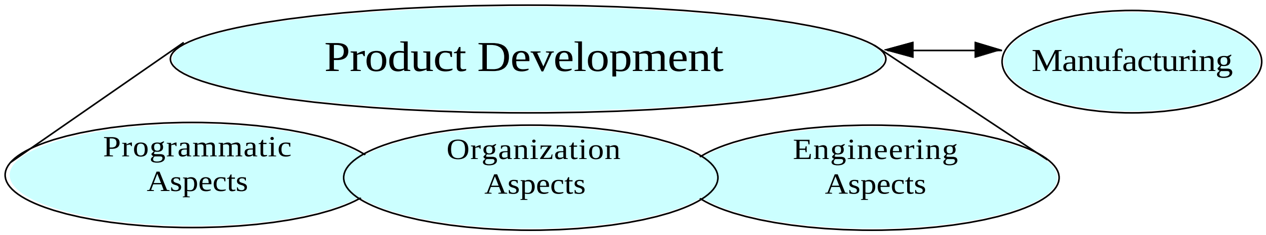
The programmatic aspects at a company level include the overall development strategy, the strategic planning process to select one project, and the resource allocations among projects in development. Shared among many of these aspects are the number of projects, the aggregate funding levels, and the relationships between projects in the portfolio. For defense projects, the government (the users, the Pentagon, and the Program Offices) largely controls the programmatic aspects of a military project at both the project and the corporate levels, as government entities determine the project objectives, allocate the resources, and define the portfolio of development projects.

Organizational aspects of development focus on how the government and companies organize to carry out the development projects. At the project level, organizational aspects may include the use of integrated product teams, the seniority of the program manager, the level of integration of government and contractor teams, and the integration of the defense contractor with its suppliers. Decisions regarding who designs the product and where are also organizational issues. Whether a particular design will be developed in-house or by suppliers is one example.

At the company or corporate level, the organizational aspects provide a framework for determining a project's structure. For defense projects, the government often determines -- or at least strongly influences -- the relationship between itself and the contractors, but the contractors and their suppliers decide how to organize to develop the projects.

Engineering aspects include the methods and tools used to design the project, and the companies' manufacturing processes. At the project level, these may include specific design tools to be used, design and review processes, the use of prototypes, and the method used to make cost, schedule, and performance tradeoffs. At the company level, these may include firms' development and manufacturing infrastructure and those of their suppliers. In developing military products, the government has traditionally required specific tools and techniques, such as a work breakdown structure, system engineering models, and information for periodic review. The government has also determined other aspects of the manufacturing process through military specifications and standards, but has recently eliminated many of these and moved to performance-based requirements. While the Program Offices request design reviews as part of the oversight of development contractors, the vast majority of decisions on designing and making the product are left to the contractors and their suppliers.

Review of a large number of papers and books on commercial product development revealed significant effort devoted to improving all three areas -- programmatic, organizational, and engineering. Figure 4-2 shows how recent commercial efforts to improve product development map against this framework, at the company and the project level.



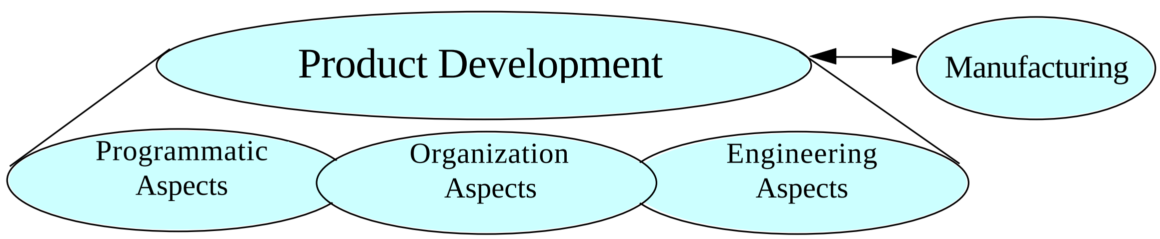
How to define a project and allocate resources	How to organize to develop the project	How to develop the project design and manufacturing processes
Company Planning Level	**Company Organization Level**	**Company Engineering Level**
Company Development Strategy Product Portfolio Management Project Screening Process Resource Allocation Process	Company Organizational Structure Functional/Team Based Structure Suppliers Involvement in Design Long-term Supplier Relations Contracting Process Structure	Manufacturing Capabilities Engineering Tools Infrastructure Corporate Engineering Capabilities Integrated Design/Cost/Technical Database Infrastructure
Project Planning Level	**Project Organization Level**	**Project Engineering Level**
Project Planning Allocated Funding/Resources Project Schedules Development Project Objectives/Requirements	Integrated Product Teams Supplier Involvement Heavy/Light Weight Program Mgr Government/Contractor Integration	Assigned Staff Capabilities and Resources Design Approach Rapid Prototyping Design for Manufacturing Computer-Aided Tools

Figure 4-2: Mapping Efforts to Improve Product Development into the Programmatic, Organizational, and Engineering Categories.

To significantly reduce development time, one would expect changes would be needed in each area. However, some areas do not currently limit development time. As the development process improves, the limiting constraint will likely change. Since the overall goal is a significant cut in development time, items in each area will likely need to be addressed to make a major dent.

A.3. Relationship to Other Lean Aerospace Initiative Research

This thesis is part of the larger Lean Aerospace Initiative (LAI), which encompasses many areas of product development. LAI research has so far focused primarily on contractor organizations and what they can do to become lean. This research has concentrated on organizational and engineering aspects of development time, not on government-related activities. Figure 4-3 shows the mapping of LAI research against the proposed framework. Because each development project may be limited by different factors, research in all three areas is required.



DoD Schedule Development Process	IPT Effectiveness	Database Commonality
	Make/Buy Decision	Software Factory
	Early Supplier Integration in Design	Design Change Reduction
	Design Structure Matrix (Organizations)	Key Characteristics
	Risk Management	Design Structure Matrix (Product)
		Architectural Innovation
		Technology Insertion

Figure 4-3: Mapping Research under the Lean Aerospace Initiative into the Programmatic, Organizational, and Engineering Categories.

.

In the organizational and engineering areas, there is significant overlap between military and commercial development projects. Some of this overlap can be seen in the focus over the past decade on using integrated product teams and advanced engineering tools and practices in both commercial and defense systems. Yet only commercial industries have significantly reduced development times, while those for defense systems have continued to increase.

Long development times are evident across all types of military projects, including aircraft, electronics, munitions, spacecraft, radar, and helicopters. Each of these areas is run by different Program Offices and defense contractors, all of which use somewhat contrasting approaches to organizational and engineering aspects. Significant effort has also already been applied in the engineering and organizational areas. This indicates that something more systematic may be affecting development times, and that the organizational and engineering areas may not be the limiting aspects.

Based on initial observations, it appears that further improvements in organizational and engineering areas, without changes in the programmatic area, are unlikely to yield desired reductions in time to develop new military products. Yet little research has been conducted in this area. I therefore decided to examine programmatic aspects to determine if they could be the key to reducing development times for military systems.

B. Programmatic Aspects and Development of the Project Schedule

The programmatic area of a project includes many potential areas for in-depth research. They include the methods and processes used to determine a project's objectives, allocation of resources to a project, selection of which projects to initiate, and determination of a project's schedule. The initial investigation revealed that many of the programmatic aspects of a project appear to be determined very early in a project's planning phase. Numerous discussions with government and contractor participants in the LAI revealed that one area -- the process used to determine a project's schedule -- appears most directly related to time to develop a product. Initial investigation also indicated that an in-depth analysis of that process would yield significant insight into the factors driving development times. A focus on a project's initial schedule can reveal the processes, influences, information, and organizations involved. It also appeared that an analysis of the process to develop and execute a project's schedule would clarify the impact of other programmatic, organizational, and engineering aspects of development time, and identify the primary causes of long times. Thus I decided to focus this research on the process used to develop a project's schedule, and its impact on eventual development time.

B.1. Preliminary Research Observations on Schedule Development Issues

In trying to identify the causes of long cycle times and narrow the research, I interviewed many people, reviewed relevant literature, and uncovered sources of schedule-related data.

The potential causes of long development time identified in initial interviews and research included advanced technology, aggressive requirements, complex users' needs, funding limitations, contractors' capabilities, testing, support requirements, and training requirements. People interviewed at the Pentagon, Program Offices, and defense contractors held disparate views of the causes of long development time and their impact. There was also a wide range of views on the importance of shortening project schedules, ranging from those who considered that effort critical to those who thought it irrelevant. Those interviewed had little information on the development of project schedules other than for those in which they were directly involved.

The primary focus of existing studies and those interviewed appeared to be meeting schedule and minimizing slip. Reducing a schedule beyond the existing plan was not a significant priority and, in many cases, not considered an objective at all. Little research was available on the development of the initial project schedule.

Interviews with industry and government representatives revealed that the Program Office's plans and expectations appeared to significantly affect a project's initial schedule. Industry representatives indicated that the Program Office's expected schedule played a large role in their proposed project schedules. One industry representative said that the government had to tell him what type of program to bid and provide guidelines to help him be responsive to the government's desires. Many industry representatives indicated they had little incentive to bid anything other than the expected schedule. Several indicated they had a disincentive to do so, since they feared they would be seen as unresponsive and assumed to pose a higher risk, and would thus be less likely to win the contract. Winning the development contract was the companies' central goal. When they do not win the contract, they are essentially locked out of the market for that product forever.

Many people stated that few positive incentives related to project schedules exist. No documentation addressing incentives related to project schedules could be found. The schedule-related data that were available from a number of sources indicated that many projects were completed on schedule and few were ever completed early.

Initial research indicated that schedule development was likely to exert a strong impact on the project's outcome but little supporting data were available. There was no agreement on the factors involved in determining a project's initial schedule, or on the structure of the process involved. Research into the process used to develop the initial schedule appeared to have significant potential to answer continuing questions and identify which factors drive project development times.

B.2. Initial Research Questions

Questions based on the initial research observations were developed to establish the scope and direction of the research. One set of questions dealt with the development of the initial project schedule. How are these initial schedules determined? Who is involved? What schedule information and tools are used? And what factors are considered important?

A second line of questions dealt with how these initial project schedules affect development of the contractor's schedules and the eventual contracted schedule. What impact does the project's initial schedule have on the contractor's proposed schedule? What are the incentives associated with the contractor's proposed schedule? What are the results of this process when comparing the government's initial schedule with the eventual contracted schedules?

A third line of questions dealt with the impact of the initial and contract schedules on a project's actual development schedule. How do a project's initial schedule and contract schedule affect the actual development schedule? What are the schedule-related incentives during the development phase? Are there significant barriers to shortening project schedules and actual development times?

These represent only a few of the questions that must be answered to understand the process used to develop the project schedule, and the impact of the initial schedules on actual development time.

B.3. The Relationship between Project Schedules and Development Time

It is important to clearly define the relationship between project schedules and product development times. Project schedules set the major milestones: they are forward projections of activities that will be accomplished as part of the development effort. Project schedules are not an objective measure but are intended to estimate accurately the time it will take to develop a product, based on the perceived and observed constraints placed on the Program Office and the contractors.

For this research a project's initial schedule is defined as the schedule used for a Milestone I decision, or for approval of project initiation. This schedule is used to plan the many aspects required to develop and field military products. A project's initial schedule is developed during early acquisition planning activities in the Pre-Milestone 0 or Phase 0 period, and are included in the acquisition Milestone I decision or its equivalent. The project schedule becomes the basis for planning activities at many levels, including those of the contractors, the testers, the funding organizations, and the users. Other significant schedules include the contract schedule between the government and the contractor to develop the product, and the actual development schedule as the project moves forward.

A project's initial schedule is not necessarily an estimate of the minimum time required to develop the project, assuming that all unnecessary activities, constraints, and delays have been eliminated. The minimum required time would be based primarily on the time necessary to define the requirements, develop the required technology, design the system to meet the requirements, and develop the process to manufacture the system. Unfortunately, it is difficult to identify the period actually required to develop a product without a good example ahead of time or a retrospective analysis.

The initial schedule is not just an unbiased estimate of the time required to develop a project -- it appears to affect the time it takes to develop the project. If initial project schedules were simply an unbiased estimate, one would expect a distribution of projects delivered before and after the date determined by the initial schedule. But Figure 1-8, which compares planned schedules with eventual development times, shows that 50 percent of projects meet their initial schedule, many are completed behind schedule, and very few finish early. The fact that so many projects finish exactly on their initial schedule appears to indicate either that those who develop initial schedules are very good at estimating the minimum time required, or that a project's initial schedule affects the minimum time it actually takes. The two are not necessarily exclusive explanations. The extent and the mechanisms of this impact are one of the key areas of this study.

If one were to develop the most accurate initial schedule, the processes used and the factors considered in developing it would be very important. If one were interested in developing a product as quickly, effectively and efficiently as possible, one would expect technology development, engineering requirements, and manufacturing development to play a central role in determining project schedules. Reducing the time required for those areas has been a major focus of many commercial firms and academic researchers. Most military initiatives have focused on integrated product and process development, integrated product teams, concurrent engineering, rapid prototyping, prototype production lines, key characteristics, computer-aided design, and computer-aided manufacturing. All these initiatives are aimed at reducing the engineering and organizational time required to develop products. But if those areas are not central to the schedule development process, they probably will not have the expected impact on actual development time.

C. Relation to Previous Schedule-Related Research on Defense Projects

Many people at distinguished organizations have examined development times for defense projects. But none have addressed the development of the project's initial schedule, or its impact on development time. Most researchers have investigated the ability of project managers to meet planned schedules and reduce delays. Several studies have examined the effects of acquisition reform on reducing cycle time and improving schedule performance. Most studies have relied on case studies although some have used statistical analysis of databases. These reports focus on the duration of projects, the deviation from the expected plan, and the estimating techniques for several types of weapon systems.

C.1. Research on Schedule Duration and Slip

It is difficult to separate the studies that examined schedule duration and slip, as the same report often includes both topics. Below is a brief summary of the research in the area.

AFSC Affordable Acquisition Approach Study

The Affordable Acquisition Approach Study, completed in 1983 by the Air Force Systems Command (AFSC), began as the Accelerated Acquisition Approach Study. This study focused on whether projects actually take longer than scheduled, or whether that is simply the perception. The study also investigated the reasons for any delays, and techniques for shortening the process of procuring systems at lower cost. The research was based on literature reviews, interviews, and analysis of 109 acquisition projects. The study found that development and production times had increased significantly over 30 years. The study identified the major cause as funding instability caused by budget cuts and ballooning project cost. The study called for longer-term planning, more program stability, and fewer projects. The study also recommended, as well as the use of program baselines, firm commitments at acquisition milestones, and program management tools. The study did not address development of project schedules but only their execution. Of note, the manager for this effort was Dr. Jacques Gansler, now Under Secretary of Defense for Acquisition and Technology.

RAND Research

The RAND Corp. has pursued several research efforts to examine acquisition costs and schedules. In a 1980 study of 67 programs, Giles Smith and E.T. Friedmann found that the demonstration validation phase was growing by 10 months per decade.[69] They found that the time required for full-scale development had not significantly changed, but that the production phase had increased by 6 months per decade.[70] This was a statistical analysis of programs based on schedule outcomes. The authors did not evaluate how the schedules were developed. In a RAND follow-up study in 1987, M.B. Rothman updated the database and looked for effects of the starting date on full-scale development but did not find a significant correlation.[71]

In 1990, RAND issued a report by Jeff Drezner and Giles Smith entitled *An Analysis of Weapon Systems Acquisition Schedules*. This report used a case study method to analyze the major drivers of schedules and deviations from the plan for 10 major defense acquisition programs. The authors looked primarily at programmatic factors such as competition, prototyping, military priority, funding adequacy, and joint service management. However, they found that the lack of documentation on the rationale for the original plan limited their insight into the factors affecting that plan and why the actual program deviates from the plan. They also found that because of the small number of programs studied, meaningful statistical analysis on many variables was not possible. Their approach was therefore generally heuristic.[72]

Drezner and Smith identified four factors with discernible, but not measurable effect on the original schedule. They found that competition in contracting generally lengthens schedules, concurrency or overlapping between development and production shortens schedules, use of prototypes lengthens schedules, and making a project a service priority shortens schedules. The authors could not discern effects from funding adequacy, separate contracting actions between development phases, external guidance, joint program management, program administrative complexity, technical difficulty, and stability of system requirements.[73] The authors also found the lack of data on schedule-related issues a significant barrier to research on program schedules and the causes of slip. Because documentation was lacking, they reported they could not evaluate the adequacy of the projects' initial schedules.

---

[69] Smith, Giles, and E.T. Friedman "An Analysis of Weapon System Acquisition Intervals, Past and Present." Contract F49620-77-C-0023, MDA903-78-C-0188 Santa Monica: The RAND Corporation, November 1980 (R-2605-DR&E/AF). Pg. 15 and Pg. 25.
[70] Smith and Friedman. 1980 Pg 30..
[71] Rothman, M.B. "Aerospace Weapon System Acquisition Milestones: A Database." Contract MDA903-85-C-0030. Santa Monica CA: The RAND Corporation, October 1987 (N-2599-ACQ). Pg. 15.
[72] Jeff Drezner and Giles Smith. "An Analysis of Weapon Systems Acquisition Schedules." R-3937-ACQ. Santa Monica CA: The RAND Corporation. Dec 1990. (R-3937-ACQ).
[73] Jeff Drezner and Giles Smith. Pg. 30.

In 1996, RAND released a significant database documenting the schedules and cost performance of several hundred major defense acquisition projects.[74] Although the study limited schedule variables to major milestones and decision, this database provides the most authoritative measure of schedule performance compared with planned schedule. Unfortunately, it does not provide insight into the factors involved in developing a project's initial schedule.

Institute for Defense Analysis

In 1989 Karen Tyson, Richard Neslon, Neang Om, and Paul Palmer issued a report examining the outcome of cost and schedule plans and the effects of acquisition reform activities on cost and schedule growth.[75] These authors evaluated the effects of six factors--prototyping, competition, multi-year procurement, design to cost, sole-source procurement, fixed-price development, and contract incentives--on 89 major acquisition programs They did not evaluate the adequacy or the development of the project schedules.

The Analytical Sciences Corp.

In 1986 and 1987 The Analytical Science Corp. released two papers on possible schedule drivers.[76] [77] These reports identified six potential schedule drivers: technical complexity, degree of technological change, system mission, procurement period, acquisition strategy, and funding profile. The first report found the physical parameters of a system marginally significant in affecting schedule. Neither effort was able to identify a combination of parameters that could account for the large variance in the engineering and manufacturing development (EMD) schedules.[78]

Air Force Institute of Technology

The research most closely related to this thesis was conducted by two British Air Force officers, Richard Hazeldean and John Topfer, who did a master's thesis on the effect of

[74] J.M. Jarvaise, J.A. Drezner, and D.M. Norton. The Defense System Cost Performance Database: Cost Growth Analysis Using Selected Acquisition Reports." MR-625-OSD Santa Monica CA: The RAND Corporation. 1996.

[75] Tyson, Karen, Richard Nelson, Neang OM, and Paul Palmer. Acquiring Major Systems: Cost and Schedule Trends and Acquisition Initiative Effectiveness. Contract MDA903-84-C-0031. Alexandria VA: Institute for Defense Analyses. March 1989 (P-2201).

[76] Nelson, Eric K. Independent Schedule Assessment FSD Study." Contract F33657-82-D-0064. Fairborn OH. The Analytical Sciences Corporation. 30 June 1986. (TR-5300-2-2).

[77] Nelson, Eric and Jay Trageser. "Analogy Selection Methodology Study." The Analytical Sciences Corporation. Fairborn OH. Contract F33657-82-D-0064. 1 December 1987. (TR-5306-7-2).

[78] Nelson, Eric, and Jay Trageser. "Analogy Selection Methodology Study." The Analytical Sciences Corporation. Fairborn OH. Contract F33657-82-D-0064. 1 December 1987. (TR-5306-7-2) Page 5-1.

contracting actions on eventual schedule performance of smaller development programs.[79] These authors painstakingly gathered schedule data on 25 smaller projects from contract records, finding that smaller contracts posted worse schedule performance than larger contracts. The authors also found that several pre-contract factors affected schedule performance: advance scheduling, the level of concurrency between development and production, the preliminary work breakdown structure, use of a network format to present schedule information, and the number of reports required. The authors also found that the methods used to manage the schedule were not well understood by Program Offices. They cited many observations from their efforts to collect data: Considerable schedule information was buried within a number of different RFP and proposal sections.

- Schedule management requirements were rarely specified in a coherent and integrated manner.
- The work breakdown structure--a primary schedule document--was usually hidden in the cost section of the proposal, implying a primary cost usage as opposed to schedule focus.
- Schedule management requirements were rarely proactive but were reactive to problems once they occurred.
- Only a limited number of techniques for managing the schedule were specified, so sophisticated scheduling tools such as PERT or contingency schedules were rarely used.
- The schedule management sections in the RFP and contracts appeared to be derived from the "Copy-From" principle taken word-for-word from previous documents.

The authors' efforts were hampered by the lack of schedule-related data for many programs and the difficulty of gathering data that did exist. Hazeldean and Topfer did not address issues related to developing the initial schedule, concentrating instead on the effect of contracting-related actions on adherence to the schedule.

C.2. Research on Schedule-Estimating Relationships

Bruce Harmon, Lisa Ward, and Paul Palmer of the Institute for Defense Analyses have attempted to estimate the time required to develop new aircraft and missile systems.[80] [81] The

[79] Hazeldean, Richard, and John Topfer. "Contracting for Schedule Performance: The Relationship Between Pre-contract Award Actions by the DoD and the Resultant Schedule Performance." AFIT Thesis. Wright Patterson AFB OH. 1993.

[80] Harmon, Bruce, Lisa Ward, and Paul Palmer. "Assessing Acquisition Schedules for Tactical Aircraft," *Cost Analysis Applications of Economics and Operations Research* (proceedings of the Institute of Cost Analysis National Conference), New York NY: Springer-Verlag. 1989. Pg. 259-280.

[81] Harmon, Bruce, and Lisa Ward. "Schedule Estimating Relationships for Air-Launched Missiles," *Cost Analysis and Estimating: Tools and Techniques* (Proceedings of the Institute of Cost Analysis National Conference), New York NY: Springer-Verlag. 1990. Pg. 115-157.

system parameters they studied included an item's weight, the number of engines, the wing area, the percentage of titanium, and many other variables. Programmatic variables included prototyping, contractor teaming, service, and contractor. These authors are now attempting to uncover a simple relationship between a system's physical characteristics and its schedule, much like the apparent correlation between weight and cost of an aircraft. But no such relationship has so far been found. The authors have found that programmatic aspects play a significantly larger role than system characteristics in determining project schedules and development times. Major drivers include funding levels, the use of prototypes, and the use of contractor teaming. Analysis of statistical relationships is limited by the lack of available data and the small number of projects studied, which included 9 aircraft and 14 missile programs.

Scott Boyd and Brian Mundt found similar results when they focused on 56 efforts to develop transport, tanker, and bomber aircraft. The authors found that only two variables they studied affected development schedule: whether the project entailed modifying rather than creating an aircraft; and whether the project included a prototype phase. No physical characteristic of the system affected time from the start of engineering and manufacturing development (EMD) to delivery of the first production item.[82] The lack of available data from which to base the analysis was cited as the most significant impediment to developing effective schedule estimating relationships.

C.3. Other Relevant Studies

The Packard Commission[83]

A central focus of the Packard Commission was comparing acquisition times between similar commercial and the military projects. The commission found that military development efforts took considerably longer and cost significantly more. The commission concluded that long cycle times were a central problem in the acquisition process and caused many other problems. The commission also concluded that military development times were excessively long and could be cut in half. It made specific recommendations for changing the structure of acquisition organizations, which were quickly implemented. But despite these changes, acquisition schedules have not been reduced. Interviews reveal that the commission's schedule-related goals are not widely recognized.

---

[82] Scott Boyd and Brian Mundt. Schedule Estimating Relationships for the Engineering and Manufacturing Development of Bomber, Transport, Tanker and Surveillance Aircraft Systems. Masters Thesis. Air Force Institute of Technology. Wright-Patterson AFB, OH. AFIT/GCA/LAS/93-2.

[83] President's Blue Ribbon Commission on Defense Management. "A Formula for Action: A Report to the President on Defense Acquisition" (The Packard Commission Report). Washington D.C. April 1986.

Defense Science Board Reports

Many Defense Science Board reports have addressed development times, beginning with the 1977 report of the Acquisition Cycle Time Task Force. Many reports have since focused on acquisition reform efforts, the use of commercial practices and components, performance-based specifications, and research and development strategies. Other studies have looked at development and manufacturing tools and practices. Analysis has been largely based on case studies, briefings on various efforts, and the judgment of the people involved. None of the Defense Science Board reports have looked at the schedule development process and its impacts on development time.

C.4. Conclusions of the Literature Review

Many respected groups have made significant efforts to identify causes of long development times. Most studies have focused on the causes of deviations from planned schedules or on total development time. A few have tried to estimate schedules based on project characteristics. Most studies report being hampered by a lack of detailed schedule-related data. No studies have addressed the process used to develop a project's initial schedule or its impact on development time.

D. Schedule Development Overview

D.1. Phases of Schedule Development

The three main phases entailed in developing and executing a project schedule include the planning phase, the contracting phase, and the development phase. Activities in each phase affect the downstream phases.

Planning Phase

The planning phase occurs in a project's initial stages, when rough schedules are developed to help organize the eventual effort. During this phase acquisition plans, strategies, and schedules, funding profiles, and program objectives are set. Development of the initial project schedule establishes the initial program objectives. These activities usually occur before the Milestone I decision to initiate the project.

Contracting Phase

During this phase the development contractor is selected and awarded a contract based on the initial plans. This phase includes developing the requirements and objectives to be part of the contract, developing the RFP, developing the contractor proposals, and selecting an appropriate contractor and negotiating the contract. Through this process, the initial project schedule is converted to a contract schedule that is binding on the government and the contractors. The contract schedule can be changed only by amending the contract.

Development Phase

Once the contract is signed, the development phase begins, and lasts until delivery of the first product. This period may include developing, testing, and producing prototypes, and other actions that affect the design of the product and the process used to make it. The schedule for this period is largely defined within the integrated master schedule and the work breakdown structure incorporated into the contract. Adherence to the schedule is tracked through a variety of methods, including technical and financial reviews.

These three phases are followed by a production phase that yields the required number of items. Schedules in the production phase affect the time required to reach operational capability, but they are not a focus of this study. For more information on production cycle times, see other research conducted under the purview of the Lean Aerospace Initiative.[84]

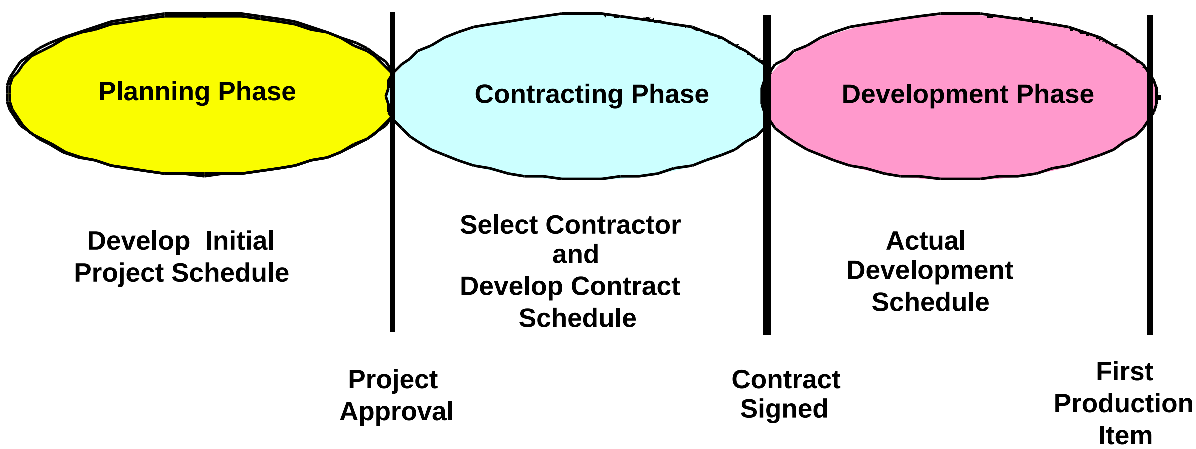


Figure 4-4: Schedule Development Phases.

D.2. Actors and Organizations Involved in Developing and Executing Project Schedules As described in Chapter 3, the product development process includes four primary organizations: the users, the Pentagon, the Program Office, and the defense contractor. These same organizations play a critical role in developing the schedule and determining the duration of

[84] Lean Aerospace Initiative research is available through the LAI web site at http://lean.mit.edu.

the development effort. These four organizations also contribute to defining and executing the development effort.

Users

The users are typically the major military command that will employ the equipment. The users develop modernization plans and requirements, as well as a preliminary program objective memorandum outlining the preferred allocation of resources. The individuals responsible for a given project are spread over several organizations: major command headquarters typically includes a planning organization, a requirements organization, and a funding organization.

The Pentagon

The Pentagon organizations key to developing program schedules are those involved in the requirements, funding, and acquisition processes. The primary interfaces between individual projects and other various groups within the Pentagon are the program element monitor, the acquisition action officer, and the requirement action officer. These officers are spread between offices of the Assistant Secretary of the Air Force for Acquisition, and the Air Force Deputy Chief of Staff for Operations, depending on the operational status of the weapon system. The various offices in the Pentagon make the final decisions on requirements, funding levels, and major acquisition issues.

The Program Offices

The Program Offices are the primary acquisition organizations in the Air Force, and are responsible for contracting for product development. Each Program Office is organized around a major weapon system or set of similar systems. The Program Office is led by a program director, typically a colonel. The average Program Office has many development programs under way, ranging from a major aircraft project to small upgrades. Each effort is led by a program or project manager, whose rank depends on the project's size, scope, and cost, and an associated team. The Program Office and the project manager are the primary links to the contractor, and they develop the acquisition plans, the RFP, and source selection criteria.

Defense Contractor

The early stages of a project may include a number of competing development contractors. The contractor's proposal includes a detailed schedule of the actions to be undertaken as part of the contract. This schedule becomes the basis for the contracted schedule used throughout the development phase. The central individual within the contractor organization is the program manager—typically the proposal manager, who has been very involved in establishing the proposed schedule. Once on contract, the program manager must ensure that the cost, schedule, performance, and financial objectives are met.

Other organizations that play a role in the schedule are the Department of Defense, suppliers, testing organizations, personnel organizations, training organizations, and logistics organizations. These organizations play a secondary role in determining schedules.

Chapter Summary

No significant effort has attempted to characterize the process used to develop the initial schedule for military development projects. Preliminary research conducted as part of this thesis indicated that the initial project schedule may play a significant role in determining the time required to develop projects. Others within the Lean Aerospace Initiative are exploring organizational and engineering avenues for reducing product development time. This indicates that research on development of the initial project schedule and its impact an appropriate focus of considerable effort.

Chapter 5

Research Methodology

A. Exploratory versus Hypothesis-Driven Research

The two major approaches to studies of this type are exploratory-based and hypothesis-based research. Exploratory research is a broader, more open-ended approach that allows examination of many factors that may affect the process in question. Hypothesis-driven research establishes a presumed mode by which a system operates and then proves or disproves the hypothesis. Hypothesis-driven research is very effective when building on research in areas with several theories of how a system works. In the area of developing initial project schedules, there is no apparent consensus and little previous research on how the process works. Any attempts to define a testable hypothesis before doing the research would not seem to stand a high chance of success in addressing all the issues that may affect initial project schedules. There are also widely varying opinions of causes of long cycle times for defense systems. Exploratory research allows many more leads and avenues of investigation to be followed and analyzed. Because of these factors, I decided that my research into the schedule development process and its impacts would have a broad scope. It would attempt to explain how the schedule development process works, and characterize the impacts on development time, rather than define a few specific hypotheses that might or might not prove relevant when the data are analyzed.

B. Level or Unit of Analysis

The individual development project was chosen as the appropriate level of analysis for this research. The typical approach has been to regard schedules and schedule slip for major acquisition programs as a single entity. This typically has limited the analysis to major defense acquisition programs or weapon systems. But the program-level data can hide the factors driving the schedules of various subordinate development projects. Those data may also mask specific problems and issues encountered with one project within an overall program.

Analysis of individual development projects allows a larger number of projects to be studied, and the factors driving each project to be identified. Smaller projects are often grouped together to form larger development programs, but they may also stand alone. Some Program Offices have a large number of project-level development efforts. One Program Office for a mature aircraft system followed over 66 different projects. Those projects can have separate schedules and budgets, and are often accomplished through different contractors or teams within a primary contractor. One example of a separate development project within a larger program is the Crew Training System for the Joint STARS Aircraft Program. But not all programs are run as separate efforts. For highly integrated development efforts such as the F-22, it is more difficult to separate many of the development efforts from the central project. In that case, it may be more meaningful to look at the entire program as a single development effort.

Another alternative is to look at the development phases--phase I: demonstration and validation, and phase II: engineering and manufacturing development--within a project. But many projects have only a single development phase, and the activities in phases I and II are often not distinct or distinguishable. A long first phase can lead to a short second phase, with no effect on actual development time.

I decided that the appropriate level for this research is the individual project level and program level, where the program could be considered a single large development project. This level provides the most information about the schedule development process and its impact on the eventual project schedule.

C. Depth versus Breadth of the Research

The issue of depth versus breadth of research is important given the limited resources and time for research projects. An in-depth study of a single area would allow for a full description of the process but might leave out related areas that may play a significant role. The issue of depth versus breadth of this research has been partially addressed by limiting this research to the area of the schedule development process and its effects on product development time. Within the specific area of development of the project schedule, the research is broader and covers a range of potential issues.

The question of depth versus breadth also applies to the individual projects studied. One can study a few projects in-depth or a large number of projects in less depth. Research conducted as part of the Lean Aircraft Initiative has relied on both broad-based surveys and in-depth case studies, depending on the objectives of the research.

The overall intent of the Lean Aircraft Initiative and of this research is not simply to identify issues in defense acquisition and the defense industry, but to improve the defense acquisition system and the defense industry. For the results of this research to achieve the desired widespread change, it must be possible to draw broad-based conclusions and recommendations that apply to a large number of projects, not just a few individual cases. Because of the unique nature of each development effort, this implies that in-depth research on even a few carefully selected projects may not be representative of the issues affecting other projects. Without a large number of case studies, it may be difficult to demonstrate convincingly that the issues in the case studies are applicable to a broader set of projects. Other research on schedules based on a limited number of case studies has not cut development times. I personally observed this result early in my research, when I presented data on one current project. My early conclusions were discounted as unique to a special case and not applicable to a broader set of projects. No set of current projects could be found that would be widely accepted as representative of the acquisition process. Each project encompasses unique circumstances and issues. Thus I decided that to have the desired impact on acquisition policy and practice, I must evaluate a wide range of projects to determine influences affecting all of them, and discover which influences affect which projects.

D. Evaluating Available Schedule-Based Data

When trying to determine what scheduling data exist, particularly for individual projects, I quickly found that very little information was available. I did identify and evaluate many potential sources of information. These are described in Table 5-1 below.

I did not locate any database or list of current project-level development efforts, let alone one that contained the needed schedule-based information. The data that could be located were often based on defense acquisition executive summaries (DAES), acquisition program baselines (APB), and selected acquisition reports (SAR). Data available through these sources are limited to major defense acquisition programs. None of the databases identified contained more than the resulting project or program schedules. The database for project schedules developed by the

RAND Corporation from the selected acquisition reports was most useful, because it was in a format that allowed for analysis.

The available data did not provide any basis for discovering what factors determine the length of schedule estimates. Justification for schedule estimates is not required, unlike for cost estimates. To conduct meaningful research on the schedule development process, I would clearly have to collect original data.

Acquisition Program Baselines: A database of program baselines is maintained by the Acquisition Program Integration (API) of the Office of the Secretary of Defense (OSD) for all ACAT I programs. These baselines consist of cost, schedule, and performance parameters. The data contained in the files consist only of the resulting schedules and do not contain any rationale or justification for the duration of the project. This information can provide information on project slip but not insight into the schedule development process.

Defense Acquisition Executive Summary: DAES is a quarterly report each major program submits to OSD detailing the progress of a particular program. The reports are maintained in paper form but are being moved to electronic files. The reports are required for all ACAT I programs. Program reporting does not occur until after projects begin, which eliminates the possibility of collecting data on the planning phases that lead to initiation of a project.

Cost Accounting Reporting System: The CARS database includes information pulled from the DAES reports that tracks cost and schedule progress. This database contains information on each major defense contract, but does not include early information on schedule development.

Selected Acquisition Reports: SAR are the official reports OSD submits to Congress detailing progress on major programs. These are similar to the DAES reports but occur annually. They do not appear to be useful in analyzing drivers in the schedule development process, but they can indicate whether programs are adhering to their planned schedules. Several groups have used the SAR reports for analyzing cost and schedule performance.

RAND Selected Acquisition Database: The RAND Corporation has developed a database from the selected acquisition reports that allows easier access to and analysis of the data. This database is limited to major defense acquisition programs and does not shed light on the schedule development process, only on the resulting planned and achieved schedules.

Defense Budget Databases: Defense budget databases are available for analysis at the Pentagon. These databases could show the amounts allocated for particular programs in a Future Years Defense Program, allowing them to be tracked over time. But although data on individual projects may be available in some cases, a majority of development efforts would be contained within major programs and not broken down into a individual budget items. The data are thus difficult to align with individual development efforts. Many such efforts receive money from different funding line items, and tracking an entire project budget is not practical given the complexity of using the database.

Milestone Approval Database: For many years, Air Force headquarters had maintained a database of major milestone decisions, but the office stopped maintaining the database several years ago owing to changes in the organization and budget cuts. This database included projected milestones but did not provide information on development or justification of the project schedule.

Requirements Document Databases: Air Force headquarters maintains a database of operational requirement documents and mission needs statements. These documents include some of the earliest actions associated with projects but do not provide a significant amount of scheduling information. Most of the information is in paper format, with only a limited amount entered into a database.

Program Office Records: Program Office records contain little information on development of initial project schedules.

Table 5-1: Available Schedule-Related Information.

E. Research and Data Collection Methods

Because a large number of projects needed to be studied to provide a clear understanding of the schedule development process, and the required data did not exist, a significant data collection effort was clearly required. Several methods and considerations were taken into account in determining the best method for collecting the needed data. Traditionally, research into defense acquisition issues has primarily focused on case studies and applied lessons from one project to future projects. This process is complicated by great differences among projects and the surrounding circumstances. Ascertaining which lessons apply to different projects, and in what cases, is difficult using the case study methodology.

Several standard research methods were evaluated for collecting information on the schedule development process. Those methods included interview-based research, archival research, case study-based research, and survey research. Each process has advantages and disadvantages, and is appropriate in different circumstances. A short discussion of the issues entailed in selecting the research method follows. The processes and a short description are included in Table 5-2 and Table 5-3.

Interview-Based Research: Interviews of key actors are an effective method for gaining a broad understanding of a process. But interviews do not supply the amount or type of data needed to convince policy makers within the Department of Defense to change course. Interview data strongly depend on who is interviewed and are open to significant interpretation on the part of both interviewee and interviewer. Groups with senior members such as the Defense Science Board often rely on interview-related research to change policies, but a less senior researcher relying on that approach was unlikely to be successful. Thus I conducted many interviews with people working at the Pentagon, Program Offices, and defense contractors to establish the scope of the research and identify the issues involved, but did not rely on them as the primary source of data for this research.

Archival-Based Research: Archival-based research relies on reviewing program documents and gathering the required information from them. A review of Program Office records was eliminated as the primary research method owing to the lack of recorded information on the processes used to develop initial project schedules. Other researchers reported similar findings.[85]

[85] Drezner and Smith. RAND Dec 1990; Hazelton and Tofler. AFIT 1993; Boyd and Mundt AFIT 1993; Harmon and Ward 1990; Tyson, Nelson, Om, and Palmer 1989.

Case Study-Based Research: Case studies provide an opportunity to examine a few projects in depth, allowing for thorough analysis of the processes entailed in those programs. The major issue is whether the results from a few programs adequately represent a majority of projects, and whether circumstances surrounding those projects are unique. The applicability of the results is highly dependent on the projects studied, and the number of case studies that might have been undertaken was limited by resource and time constraints.

Nevertheless, I did conduct an in-depth case study as well as several more limited case studies to identify and frame the issues. This research was invaluable in developing the surveys.

Survey-Based Research: A survey method allows for study of a larger number of projects but not at the depth of a case study. The types of questions that can be asked and the total length of the survey limit survey-based research. But proper sampling methods and a large number of respondents can ensure that the results accurately reflect the population of projects. Such surveys can reveal the general nature of the process used to develop project schedules. Relying on data collected from an array of defense development projects provided a more robust database from which to draw conclusions and base recommendations.

For this research, a broad-based survey of current development projects offered a better opportunity to specify the general nature of the process. The broad-based survey ensured that the results would be representative of the schedule process as a whole and not just the particular circumstances surrounding a particular project. The survey method was augmented primarily by interviews, case studies, and literature reviews to understand the issues involved both before developing the surveys and during analysis of the results. Discussion groups and interviews were conducted at product centers and within the Lean Aircraft Initiative to review and help interpret the survey results to gain a full understanding of their meaning.

Method	Advantages	Disadvantages
Interview Research/Discussion Groups	Easy to conduct Does not rely on extensive data collection Captures experience of others	Results dependent on the experiences of those interviewed Difficult to rectify difference of opinion Unlikely to change policies
Archival Research	Data recorded at time of events	Limited schedule-related data available. Difficult to understand issues involved. Poor documentation of development of

		initial project schedules.
Case Study Research	Allows for in-depth examination of schedule development issues on several projects	Limited number of potential projects Each project has special circumstances that may make drawing broader lessons difficult
Survey-Based Research	Allows for a large number of projects to be studied Allows statistical analysis of results	Limited insight into each program Limited to size and scope of survey Limited to depth of questions
Literature Research	Many sources on commercial product development efforts	Few authoritative sources on developing defense products No literature on developing project schedules for defense systems Lessons from commercial projects may not apply to military projects

Table 5-2: Summary of Advantages and Disadvantages of Various Research Methods Considered or Used in this Research.

Method	**Initial Research Scoping**	**Schedule Development Research**	**Follow-up Analysis and Interpretation**
Interviews and Discussion Groups	Many interviews were conducted with a wide range of people from government, industry, and academia to understand issues related to development time.	Used to develop and test the survey. Ensured data availability.	Interviews and group discussions were used to understand survey results and screen recommendations.
Archival Research	Used to locate available data. Few useful data found at Program Offices.		
Case Study Research	A major case study and several smaller case studies were conducted to understand the issues involved in developing project schedules.	Results of case studies used to develop surveys.	
Survey-Based Research		Three surveys used to collect data on projects.	Analysis based on database from surveys.
Literature Research	An extensive number of books, papers, articles, and course material were	Used to identify potential survey questions and wording.	

	reviewed to set scope and frame for the research.		

Table 5-3: Research Methods Used During Various Stages of Research.

Chapter Summary

This research selected an exploratory vice a hypothesis-driven research approach. Little previous conclusive research and widely varying opinions among defense leaders indicated that a broader study of the schedule-related issues was warranted than hypothesis-driven research would allow. The individual project was selected as the appropriate level of analysis for this research as it was felt that only at the individual project level could the factors influencing a project's schedule and the impacts of that schedule be determined. An analysis of the available schedule related data indicated that significant data collection would be required. To collect the data, the survey-based method was selected as the appropriate method as it allowed for a wide array of projects to be studied.

Chapter 6

Project Surveys: An Overview of Program Office, Contractor, and Pentagon Surveys

A. Survey Objectives

The objectives of the surveys for this research were to document and describe the schedule development process and its impact on eventual product development times. The surveys did this by gathering information about projects representing a cross section of defense aerospace products. Two of the surveys for this research were conducted jointly with Dr. Eric Rebentisch of the Lean Aircraft Initiative, who was studying issues associated with managing programs with unstable funding.

B. Overview of the Three Surveys

Prior to developing the surveys, I identified the key players that influence schedules, and the types of information needed to characterize the schedule development process. I recognized that respondents' perspectives might depend on the organization to which they belong and the level from which they view the development effort. To obtain a comprehensive look at the schedule development process across various organizations, a multi-level set of surveys was chosen. These surveys were conducted at the Pentagon, the Program Offices, and the defense contractors.

The three surveys were designed to collect information on the development of project schedules and the projects' adherence to those schedules. The surveys were structured to gather the information readily available to people working in the different organizations. The three overlapping surveys were also designed to provide either corroborating or supporting responses among organizations, and to identify and highlight the differences.

To obtain information on individual projects, the surveys targeted project managers in the Program Offices, project managers in prime contractor companies, and program element monitors or action officers in the Pentagon. These people were in a position to possess the most knowledge and understanding of the schedule development process, as they make decisions or at least make recommendations for their projects within their organizations. The surveys were time-phased to allow me to identify additional areas of interest, add questions, and change wording on subsequent surveys. The surveys were completed over a one-and-a-half-year period. The Program Office survey was mailed in January 1996 and returned by June 1996. The contractor survey was mailed in June 1996 and returned by October 1996. The Pentagon survey was mailed in January 1997 and returned by May 1997. The difference in timing did not affect the results, as many of the projects have been in development for significantly longer periods, and the time required to change the system is significantly longer than one year.

C. Survey Development

A literature search was conducted to uncover factors affecting both defense and commercial product development. A list of potential questions was developed to cover the range of issues associated with developing project schedules.

The first survey developed was the Program Office survey, designed to explore issues associated with both schedules and program instability.[86] Several different types of questions were created to gather factual and perceptual data from respondents. Questions to gather factual data requested specific information believed to be readily available to respondents based on pre-test results.

Some of the needed information concerned people's perceptions and interpretations of events and their influence. Thus while most questions were specific to make data analysis easier and force concise responses, some open-ended questions were included to give respondents an opportunity to explain specific circumstances. Different scales were used depending on the nature of the questions and the information desired. In all cases, the questions were structured to collect the required information and to ease the burden on respondents. Examples of questions and the method used to analyze the results can be found in Chapter 7.

The surveys were organized into major sections that focused on the characteristics of individual projects, their costs and cost growth of projects, scheduled-related information, and personal information on respondents. This separation is more evident in the later surveys, as significant learning occurred during collection of the data from the first survey.

Each survey was reviewed and pre-tested in several settings. Throughout their development, draft copies were assembled and circulated among fellow researchers for comment. Early drafts were then reviewed by a sample of program managers at Hanscom Air Force Base (AFB) in an interview format. After their comments were incorporated, the survey was given in final draft form to 15 project managers at Hanscom AFB. These program managers provided both data and comments on the survey. They also estimated the time respondents would need to complete the survey (between 1 and 3 hours, depending on their direct knowledge of a project), and a breakout of the time required for each section. These people's comments and suggestions on both content and wording were very helpful and were incorporated into the final survey. Subsequent surveys used questions similar to the Program Office survey and were reviewed by the respective organizations and a representative group of potential respondents prior to distribution.

D. Survey Limitations

The survey method has a number of limitations: The number and content of questions that can be asked are limited, and the length of the survey must be limited to avoid affecting the response rate significantly. The information collected is also dependent on the respondents' knowledge of the events in question, their ability to find the information, and their willingness to provide that information. The accuracy and completeness of the responses cannot be controlled.

A target limit was placed on the number of pages of the survey based on survey literature. Prior experience within LAI also indicated that the response rate would decline proportionally with the length of the survey. Every effort was made to limit the questions to areas deemed necessary to

[86] The Program Office survey and the contractor survey were conducted jointly with Dr. Eric Rebentisch with the Lean Aircraft Initiative. Dr. Rebentisch was studying Program Instability in Defense Projects. His research is available through the Lean Aircraft Initiative. "Managing Under Program Instabilities." LAI Draft report.

describing the scheduling process and instability issues. The length of the contractor survey was limited even further at the direction of the sponsoring organizations.

Surveys are also limited in their ability to measure prior events, as people's recollections may fade and later events may affect interpretations. This is a problem with all research. A decision was made to use the retrospective approach because of the excessive time entailed in in-situ research. There was no option other than to rely on respondents' recollection and understanding of events.

Surveys are also limited by the willingness of respondents to provide information. To surmount concerns about the use of the information, strict assurances of confidentiality were provided. I promised that the information would be masked if it became apparent that an outside person could connect the responses with a specific project.

E. Organizations Surveyed

When determining which organizations to survey for the Program Office survey, Dr. Rebentisch and I decided to include those focused on the entire selection of aerospace products across all three services. Previous studies had been severely limited in the number of projects, which in turn limited the use of statistical analysis. Surveying all aerospace development projects, and not relying on any predetermined selection criteria, avoided any selection bias. The projects included would depend only on the cooperation of the organizations and individual respondents.

Air Force organizations identified included groups from all three services. The Air Force organizations were the Aeronautical Systems Center at both Wright-Patterson Air Force Base and Eglin Air Force Base, the Electronic Systems Center at Hanscom Air Force Base, and the Space and Missile Systems Center at Los Angeles Air Force Base. The Navy organization primarily associated with developing aerospace products is the Naval Air Systems Command (NAVAIR). Army organizations associated included the Army Aviation and Troop Command (ATCOM) and the Army Tactical Missile and Missile Defense programs at Redstone Arsenal. Other Air Force projects run from the Air Force Air Logistics Centers were not primarily development efforts and were not included in the surveys. Often an associated Program Office within the various development centers runs many of the development projects for mature systems, primary responsibility for which is formally transferred to logistics centers. We decided that excluding the logistics support centers would not compromise the representative nature of the project samples, and would not impact the integrity of the survey.

The population of development efforts included a wide range of project sizes and a wide variety of systems. Since the goal was to describe the schedule development process across the entire range of projects, it was important to include the full range within the target survey sample.

To develop a list of ongoing projects and their project managers, we contacted all the development centers. Many of the product centers did not maintain a list of ongoing development projects but instead provided lists of the organizations involved. No centralized list could be found, for example, of ongoing development projects at the Air Force level, the center level, or even the Program Office level. In many cases, it was necessary to call each Program Office directly and speak with various team leaders to identify the set of ongoing projects. Despite significant efforts, a suitable list of projects was not developed from the Air Force Space and Missile Systems Center, and its participation in the study was dropped. In several cases the organizations requested that the smallest projects be excluded (Aeronautical Systems Center and ATCOM), or provided only the major programs (NAVAIR). This resulted in a higher percentage of larger programs in the sample than may occur in the population of projects as a whole. Both the Aeronautical Systems Center and the Electronic Systems Center provided information on a large number of projects and significant support in ensuring that the surveys were completed. As a result, a significant percentage of the returned surveys represent ASC and ESC programs. As will be shown later, there was no significant difference in survey results between larger and smaller projects or among different product centers. Thus there did not appear to be any bias effect stemming from the surveyed population. In total, 430 ongoing projects were identified at the Program Office level, and surveys were mailed to all 430 project teams.

The contractor survey relied on the willingness of the companies to participate and our ability to identify suitable projects and appropriate respondents. Two methods were used to identify projects for this survey. The Program Office survey asked the program managers to identify the contractor program manager and provide an address. And companies participating in the Lean Aerospace Initiative helped identify projects. The sampled population included all projects identified in the Program Office survey and all projects identified by LAI associated contractors that elected to participate.

An effort was again made to identify every significant development project and send a survey to each. No effort was made to select or exclude specific projects from the survey based on performance. In addition, we agreed to shield from people other than the researchers any identifying information that would allow responses to be associated with a specific project. In total, 250 individual projects and their program managers were identified for the contractor survey.

For the Pentagon survey we adhered to the same philosophy of identifying the entire population of interest and sending surveys to all. The Office of the Assistant Secretary of the Air Force for Acquisition provided a list of all Air Force program element monitors and associated action officers. As we attempted to identify Army and Navy program element monitors, we discovered that those services consolidated their program elements, providing less insight into individual development projects. We therefore decided not to include Navy and Army program element monitors in the Pentagon survey.

The list of program elements and program element monitors was screened to eliminate the elements that clearly did not oversee any development efforts. Surveys were mailed to all 225 program element monitors and action officers who might oversee development efforts. Approximately 100 of the 225 program element monitors responded that they did not oversee any appropriate development-related activities.

Since many of the program element monitors oversaw several program elements containing many development efforts, each monitor and action officer was asked to answer only one survey for a single project with which the officer was most familiar. Having the program element monitors complete more than one survey was not seen as practical nor likely to be successful. While this allowed less control over the population of projects and may have allowed for some selection bias on the part of the monitors, the returned surveys matched the general demographics of the other two surveys. We judged that data obtained on projects with which the monitors were most familiar would be of higher quality and more accurate than responses on a project they were only peripherally aware of. Allowing the monitors to select the project was assumed to boost the response rate.

We did make a largely unsuccessful attempt to direct program element monitors to projects already included in the Program Office and contractor surveys, to provide direct overlap. But the limited number of respondents and less-than-optimal response rates resulted in a low number of overlapping surveys. Only 8 surveys pertained to projects in both the Pentagon and Program Office surveys—not enough for meaningful statistical analysis. A visual inspection of the responses did not reveal any large differences between Pentagon and Program Office responses on the same projects.

In total, 905 potential respondents were identified at the Program Offices, the defense contractors, and the Pentagon levels. Surveys were identified by project and addressed to the project manager or program element monitor of the specific project identified. Program element monitors with several projects were mailed a single survey and asked to select a single project as described earlier. A survey number tracked each survey.

F. Response Rate and Efforts to Improve It

Prior to and following the distribution of each survey, significant efforts were made to improve the response rate. Efforts taken prior to the Program Office survey included obtaining senior management support at the product centers and among the Air Force acquisition staff. Mr. Blaise Durante, Deputy Assistant Secretary of the Air Force for Management Policy and Program Integration, signed a cover letter directing the Program Offices to complete the survey.

A multi-step process was used to boost the response rate following distribution of the Program Office surveys. A follow-up letter to each recipient was sent, succeeded by phone calls. A few weeks later, a message was sent from the commander's office at each product center directing recipients to return the surveys. A few weeks later a list of people that had returned the surveys and those that had not was provided to the command sections of each center, and a second message from the commander's executive officer was sent to each recipient. Later additional individual calls were placed to individuals to encourage them to return the completed surveys. Replacement surveys were mailed to those who had lost them, and additional surveys were provided to the individuals requesting them when contacted.

The efforts to boost the response rate did not have a dramatic effect on the number of surveys returned. Similar efforts were made for the contractor and Pentagon surveys.

The final response rates for the three surveys were 35 percent for the Program Office survey, 42 percent for the contractor survey, and 49 percent for the Pentagon survey. This excludes responses from the program element monitors that indicated that they did not have any development projects within their program elements.

G. Respondent Profiles

Between the three surveys, 317 completed usable surveys were received: 151 Program Office surveys, 104 contractor surveys, and 62 Pentagon surveys. Surveys and responses received but incomplete or lacking information were not included in the analysis. The complete list of projects whose managers responded is provided at the end of the chapter in Tables 6-1, 6-2, and 6-3.

The projects represented in the responses can be characterized in many different ways, including by cost, acquisition phase, product type, production cost, and year the project was initiated. That information is provided to show the types of projects from which the data are culled. Because no description of the total population of development projects is available, no comparison to the total population can be made. The consistency of the distribution and project characteristics across the three separate surveys provides some evidence, although not proof, that the surveys represent a reasonable cross section of ongoing Air Force development efforts.

The respondents oversee different types of projects, from aircraft-related systems through software-dominated systems. Figure 6-2 below shows the distribution across different types of systems. The responses cover a significant number of projects from each category, with a large number from aircraft avionics programs. The absence of spacecraft-related systems in the Program Office survey and the contractor survey is due primarily to the exclusion of the Air Force Space and Missile Systems Center from that survey, and to the focus of the companies involved in the Lean Aerospace Initiative at that time.

The projects can also be grouped into acquisition categories (ACAT), defined by the size of the project. ACAT I projects are the largest, with over $355 million in development costs and $2.1 billion in production costs. These are considered the major defense acquisition programs. ACAT II projects have between $355 million and $140 million in development costs. ACAT III and IV projects have less than $140 million in development costs. There was no significant difference between the distribution of ACAT levels between the Program Office respondents and Pentagon respondents, indicating that they represented a similar distribution of projects. Comparison of the distribution of ACAT projects with the contractor survey was complicated by the large number of respondents who did not indicate the ACAT level for their development effort.

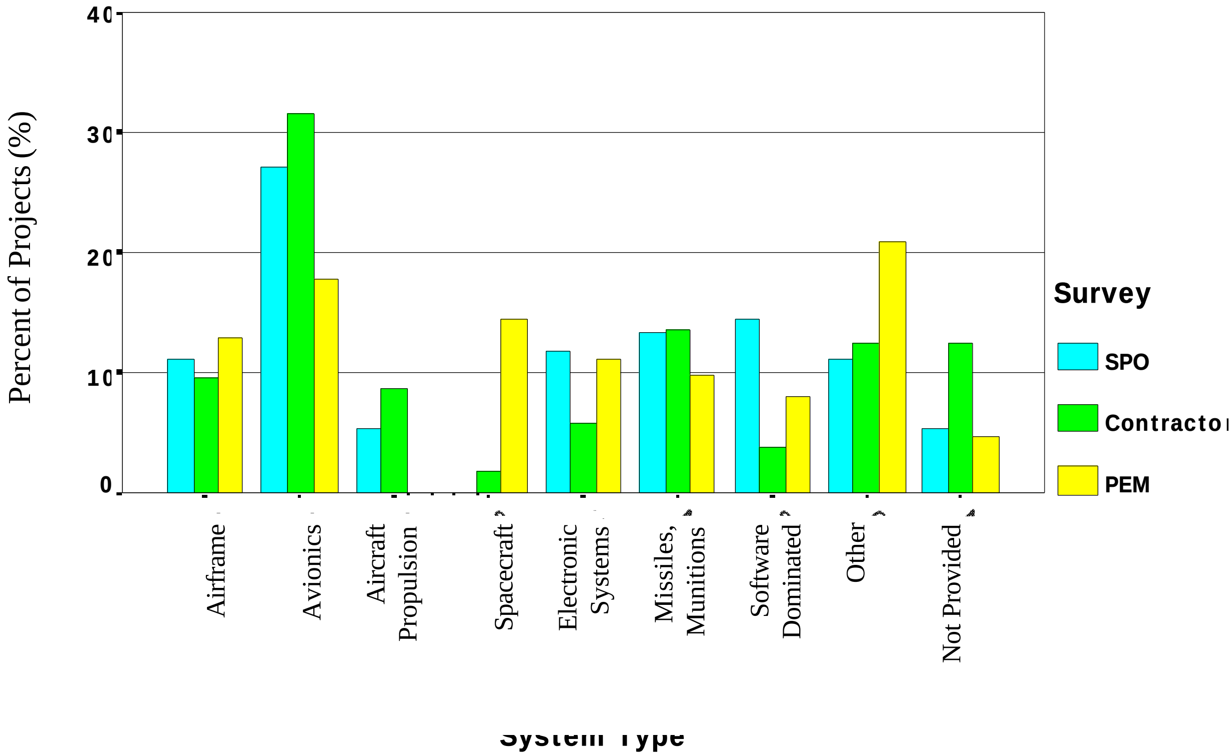


Figure 6-1: Percentage of Respondents by Survey and System Type.

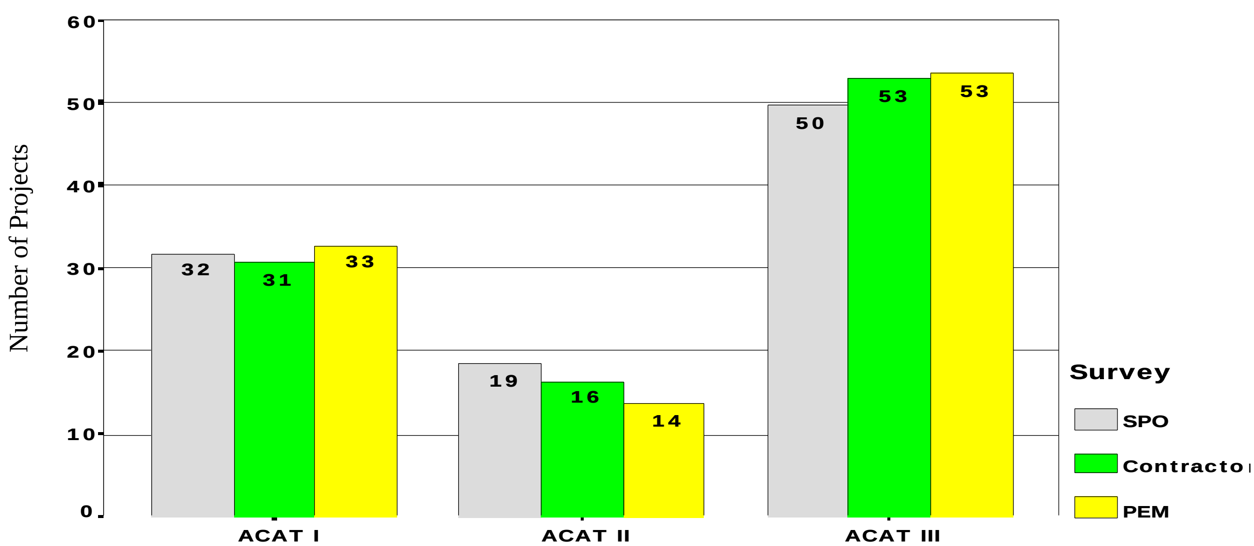


Figure 6-2: Distribution of the Acquisition Category (ACAT) of Responding Projects by Program Office, Contractor, and Pentagon Surveys.

Identifying the acquisition phase of a project provided another way to characterize the respondents. The largest number of projects were in the engineering, manufacturing, and development phase or earlier stages. A significant number were in the production phase, and a few were in the operations/sustainment and close-out phases. Projects covered in the Program Office survey had a higher probability of being in the production phases than the projects covered in the other surveys.

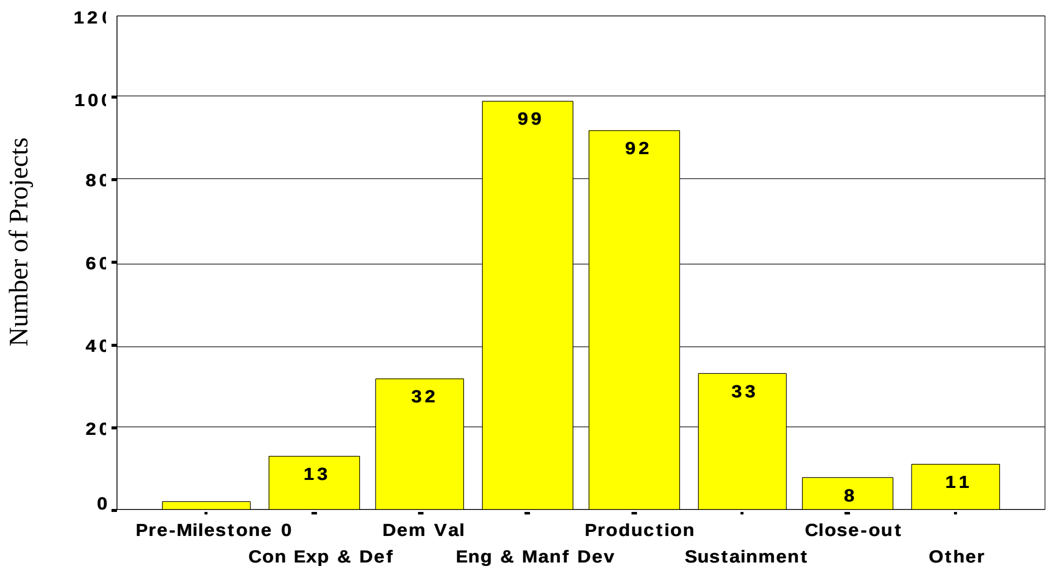


Figure 6-3: Total Respondents by Acquisition Phase.

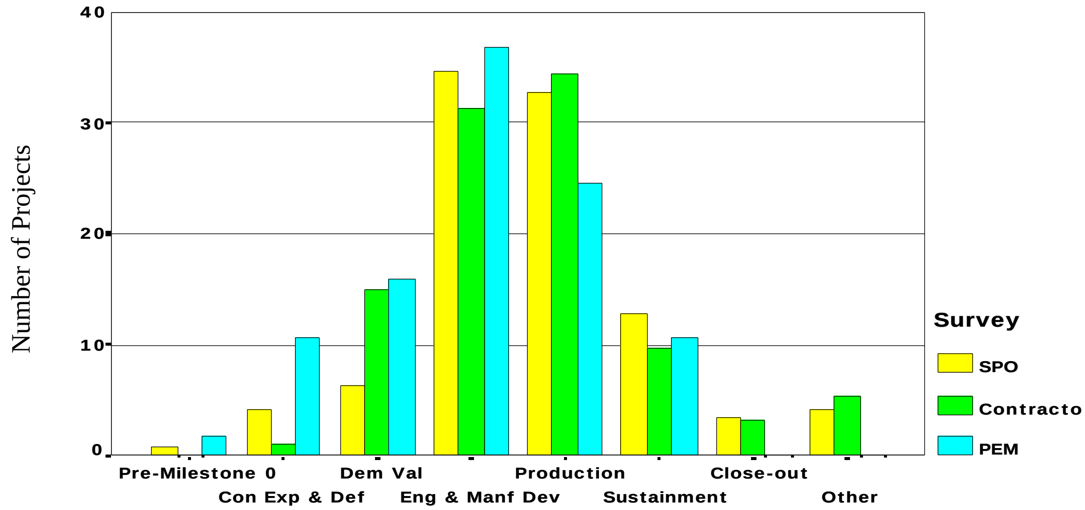


Figure 6-4: Respondents by Acquisition Phase for Program Office, Contractor, and Pentagon Surveys (Number of Projects = 317).

The projects surveyed can also be characterized by the amount of technological advance required in their systems. As would be expected, a significant number are based on either a new technological generation or incremental improvements, and a smaller number are based on revolutionary development or little or no improvement. When broken out by survey, the responses indicate no significant difference between the surveys and expected results as if they had sampled the same general population.

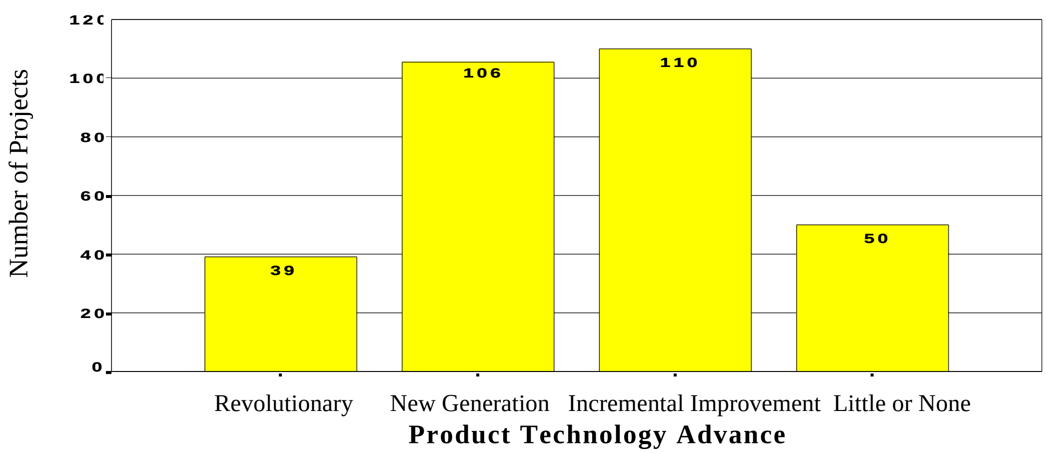


Figure 6-5: Respondents by Amount of Technological Advance in the Pentagon, Program Office, and Contractor Surveys (Number of Projects = 317)

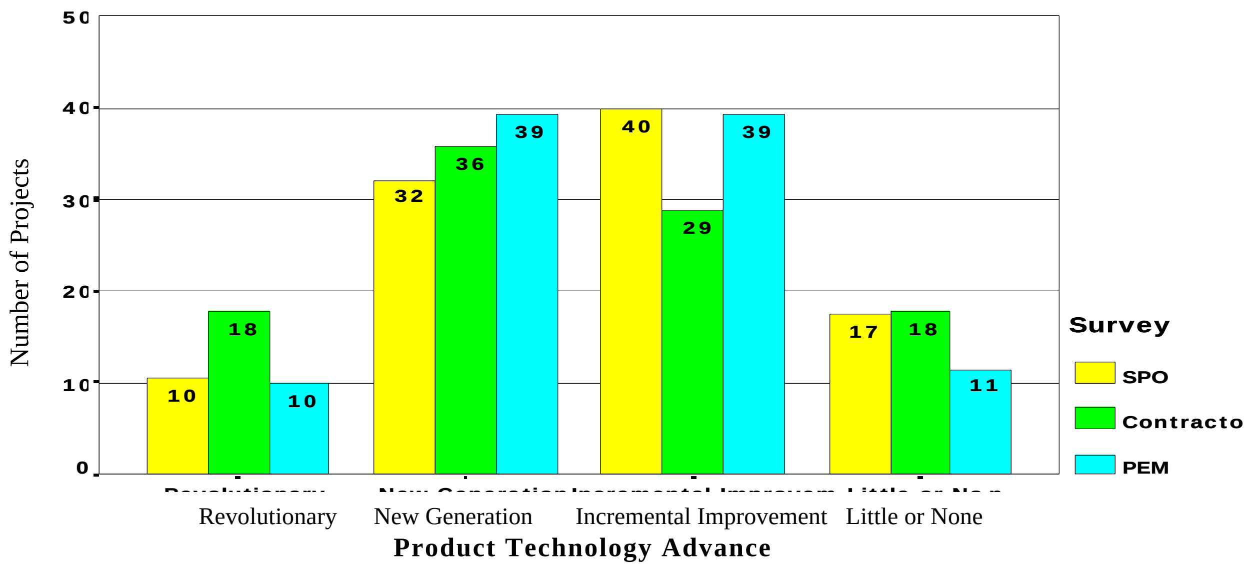


Figure 6-6: Distribution of Respondents by Level of Technological Advance for Program Office, Contractor, and Pentagon Surveys (Number of Projects = 317)

Another way to characterize respondents is by the cost of the development effort they oversee and the cost of the expected production effort. In the following charts, the cost of the systems is grouped by the order of magnitude of the cost of the development and production phases.

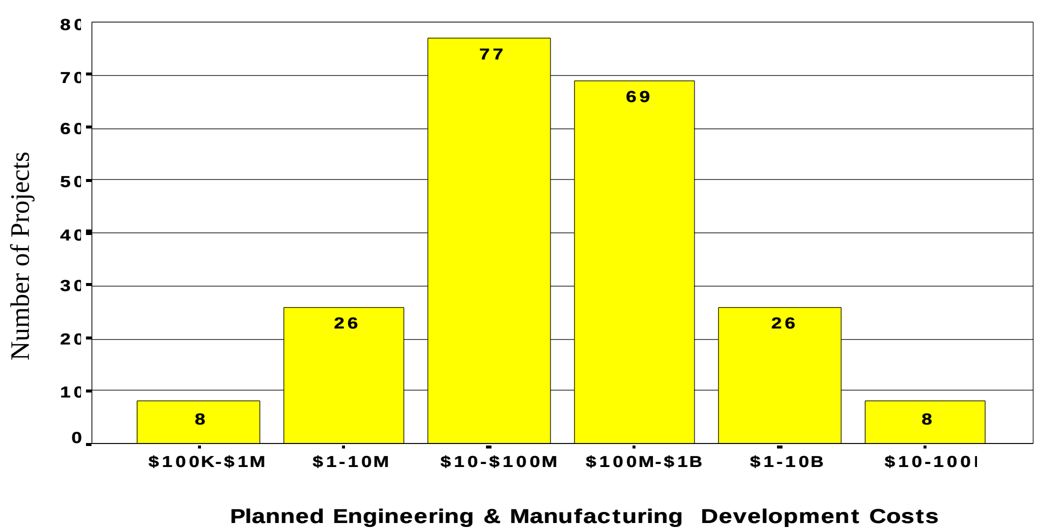


Figure 6-7: Planned Pre-EMD and EMD Cost of the Projects Surveyed.

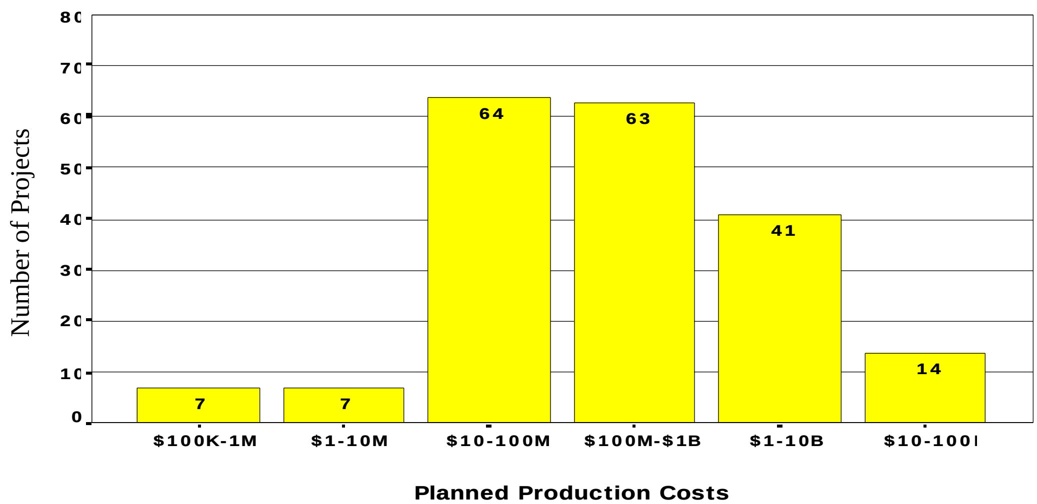


Figure 6-8: Planned Production Costs of the Projects Surveyed.

Another way the projects can be characterized is by the year of their initiation. Most of the projects respondents described are less than five years into their development phase. This indicates that they represent current development practices. This also indicates that many respondents had firsthand knowledge of the information requested, or enough knowledge of the corporate schedule development process to answer the questions accurately. Many older projects were also included by respondents, some dating back a considerable length of time. The dropoff in the number of projects started in 1996 may reflect the timing of the surveys. The Program Office survey was conducted at the beginning of 1996, so projects begun after that date would not be included.

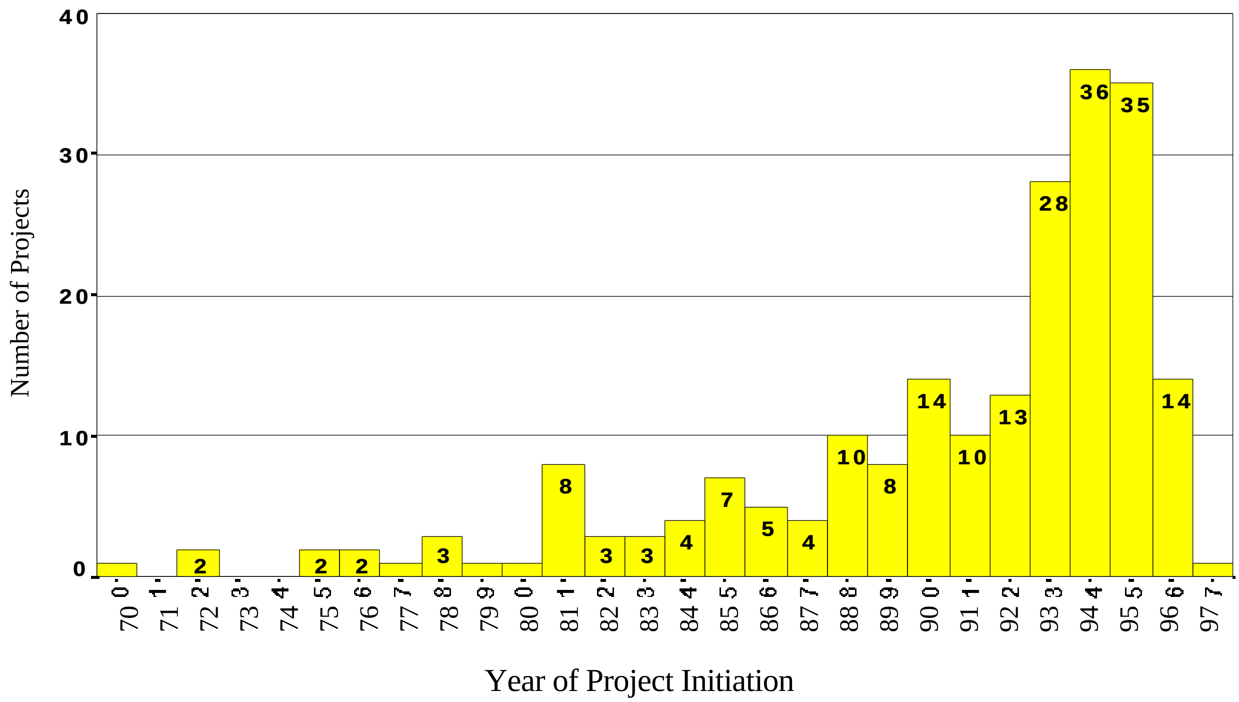


Figure 6-9: Year of Program Initiation by Survey Respondents.

The apparent bias of the respondents toward more recent programs is preferable, in that they represent current development practices. That means that the survey results indicate how acquisition processes are presently working, and not necessarily how they have worked in the past.

There is a wide spread of development times. The average time from program initiation to first production item was 76 months. A significant number of projects reported development times in excess of 10 years.

umber of Projects

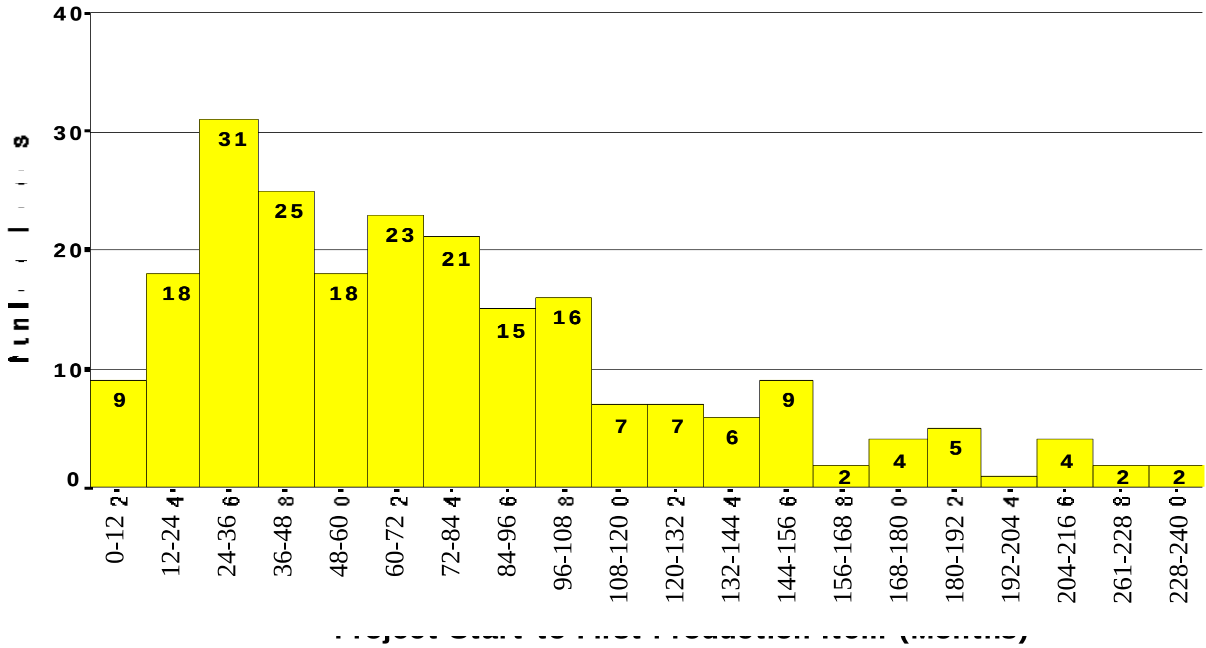


Figure 6-10: Development Time from Program Initiation to Delivery of the First Production Item for Surveyed Projects (Number of Projects = 225; Average Development Time = 76 Months)

Since there is no available list or characterization of all ongoing projects that could be used as a comparison, it is not possible to determine if survey respondents represented a cross section of ongoing projects. The similarity of distribution of project characteristics among the three surveys has already been noted. These similar distributions include the type of project, the size of projects (ACAT), the acquisition phase, and the scope of the technological advance. These results provide additional confidence that the surveys fairly represent the set of ongoing projects.

Chapter Summary

The three surveys were designed to gather the necessary data on the schedule development process from Program Offices, the Pentagon, and defense contractors. The survey attempted to survey all military aerospace defense projects. A total of 317 completed responses were received. Characterization of the responses indicated that they adequately represent current military aerospace development efforts.

Table 6-1

Projects Overseen by Pentagon Survey Respondents (Program Element Monitors and Action Officers)

60K A/C loader

Aces II Ejection Seat

Advanced EHF

Advanced Airborne Interceptor

AIM-9X

Airborne Laser (ABL)

AMRAAM P3I P3

AWACS Multi-Source Tactical System

B-1B Defensive Avionics Upgrade

B-52 Advanced Weapons Integration

C-130 AW/APN-59 Radar Replacement

C-130J

C-130J Aircraft Annex

C-141 All Weather Flight Control

CTAPS 5.2 Software

CV-22

Combat Survivor Evader Locator

Common Missile Warning

Defense Satellite Communications

Deliberate Crisis Action Planning Deployable C3 Communications

DIRECT

EARC Night Vision Imaging System

Environmental Satellite System Evolved

Expendable Launch Vehicle

F-16 NVIS Pre-Block 40

F-16 Onboard Oxygen Generator

F-22

GCSS-AF

Global Weather Analysis and Prediction

Guidance Replacement Program

Have Stare

IMDS

IW Weapon System Vulnerability

KC-135 Multipoint Refueling System

KC-135 Simulator Upgrade Visual

Joint Air to Surface Stand-Off Missile

Joint Strike Fighter

Joint SIGINT Family

JSESST

Life-Cycle Cost Reduction Initiative

MILSTAR Terminals

NCMC- TW/AA System

NPOESS (National Polar Orbiting Environmental Satellite System)

Predator UAV

Small Tactical Terminal (STT)

SOF/Rescue

Space-Based Infrared System (SBIRS)

Space Warfare Center

Strategic War Planning System

SSMIS Tactical Weather Radar

Titan IV Space Boosters

Theater Airborne Reconnaissance System

Tri-Service Embedded GPS/INS

Wind Corrected Munition Dispenser

Table 6-2 Projects Overseen by Contractor Survey Respondents (Program Managers)

A-10 Laste
A2100 LDAs
ABL - Airborne Laser Program
AC-130 NAV/FCO Test Bed
Advanced IRST
Advanced Propulsion Materials
Affordable Multimissile Manufacturing
Air Route Surveillance Radar Mode
ALQ 131 FMS
AN/ALQ-126B
AN/ALQ-144/144A
AFMSS
APG-73 Phase 2 (Recce)
Advanced Unitary Penetrator
AF Joint Technology Demonstrator
Affordable Composites for Propulsion
Anti-Helicopter Munition
ANAPQ-174D MMR EMD
ARPA Advanced Ceramic Technology
Autonomous Intelligent Submunition
AV-8B Re-manufacture
B-1B Avionics
B-1B Bomber Integrated Logistics
B-1B Conventional Mission Upgrade
B-1B Production/AN/ALQ-161A
B-1 Training System
B-2 Parts EMD
B-2 Parts Production
Boeing 777 Floor Beams
C-12 Avionics Prototype kits
C-17
C-17 Aircrew Training System
C-130 H2
C-130J Displays and Computers
Combat DF
Commercial Turboprop
CV-22
DELTA III
E-6 Orbit Improvement Systems
EF-111 System Improvement Program
Exoatmospheric Kill Vehicle Sensor
F-14 LANTIRN Integration
F-15
F-15 AVTR
F-15 APG 63(V)1 (APG-63 Radar RM
F-15S to Saudi Arabia FMS
F-16
F/A-18 E/F
F/A-18 E/F AMAD Aircraft Mounted
F-22
F-22 EW
F-22 RAIU
F-22 CNI
F-22 Main Electric Power Generator
F-22 Radar
F117 Propulsion for C-17 Aircraft
F100 Component Improvement Program F414
FADEC
Gunship Spares
Horizontal Technology Integration Integrated ESM
JDAM - Joint Direct Attack Munition
Javelin
Joint Air to Surface Stand-Off Missile
Joint STARS
Joint Strike Fighter
JPATS - Joint Primary Aircraft Training
LANTIRN F-14
Launcher Avionics Package
LCA IFCS
LMD/KP
Longbow
Longbow Apache
Longbow FCR
Longbow Missile
M-1 Tank (General Dynamics)
MAFET Thrust 2
Mast Mounted Sight
Milstar Terminal (AF)
Missile Tracking System
MQM107D
Navy Landing System
Navy Joint Technology Demonstrator
Peace Shield
RAH-66 Comanche
RAH-66 Comanche CNI
SEA Transmission
Sensor-Fuzed Weapon
Sensor-Fuzed Weapon - P3I Improvement
SLAM (ER)
Space Station Communication System
Space Station - Power Module
SR-71 Elint Production
Tactical Endurance SAR
T-1A Trainer
T-56 Turboprop Engine
TAD/PNVS
THAADS
Tier II+ Wing
TLOS
Trident D5 Missile TMK Translator
V-22
Wavelet Insertion Demonstration

Wide Area Munition

Table 6-3
Projects Overseen by Program Office Survey Respondents (Program/Project Managers)

AC-130U Gunship
Advanced Interface Control Unit
Advanced Cruise Missile
Advanced Strategic and Tactical
Aerial Targets
Aircrew Integrated Helmet System
AIM-9X
Air Combat Command Training Prog
Air-To-Ground Missile Systems
AGM-129
Alternate Processing Correlation
AMC C2 IPS Info Processing
AMRAAM AIM-120A/B/C/ Missile
AN/ALE-47
Apache Countermeasure Dispenser
Apache Attack Helicopter
Apache - Longbow
AV-8B Remanufacture
AWACS
AWACS - Saudi
AWACS - 767
AWACS RSIP
AWACS Comm Extend Sentry
AWACS Engine Extend Sentry
AWACS PDM Re-Engineering
Avionics Strategic Planning
B-1B Aircraft Program Director
B-1B Aircraft Conv Munition
B-1B Computer System Upgrade
B-1B Defensive System Upgrade
B-1B Mission Planning System
B-1B Training System
B-2 Aircraft Training System
B-2 Aircraft Integration
B-2 Aircraft Production
B-2 Engine
B-2 MSN Planning
Base Information Protection
Big Safari
Broad-Based Environment for Test
C-17 ATS Program Branch
CV-22
C-32 (VC-X)
C-130 H2 Aircrew Training System
C-130J Aircraft
C-141 Aircrew Training System
CCAWS Project Office
Coatings Technology Integration
Cockpit Air Bag System
Combat Intelligence System (CIS)
Command and Control SPO
Command Center Processing
Common Mapping Production
System Common Missile Warning
Directed Infrared Countermeasures
DoD Advanced Automation Systems
DSU-33
Embedded GPS/INS
Engine Model Derivative Program
Engine Component Improvement
F-16
F-16 Block 30 Targeting Pod
F-16 Common Configuration
Implem F-16 Common Missile
Warning
F-16 FMS
F-16 Night Vision Imaging System
F-16 RWR
F-22
F-22 Aircraft Air Vehicle
F-22 Aircraft -- 199 Engine
F-117A Aircraft
F117 Engine - Propulsion for C-1
F117-PW-100 Engine - Propulsion
Ground Theater Air Control System
H-1 Marine Upgrades Program
HAE UAV
HIDAR & MEECN
IDECM
Intelligence and Information War
Intelligence Data Handling System
IDHS-Automated Message Handling
IDHS-MAXI Integrated Avionics
IDHS-Sentinel II Integration
IDHS-IC4I Intelligence Receivers
ITAS
Joint Advanced Strike Technology
Joint Direct Attack Munition
Joint Helmet Mounted Cueing Sys
Joint Primary Aircraft Training
Joint Programmable Fuze (JPF)
Joint Service Electronic Combat
Joint STARS
Joint STARS - Deployable Mission
Joint STARS - Flight Crew Train
Sys Joint STARS - TADIL-J
JTIDS
KC-135 Aircrew Training System
KC-135 Improved Aerial Refueling
Kiowa Warrior
Kiowa Warrior
Large Aircraft Directed Infrared
MC-130H Combat Talon II
MILSTAR Terminal Command Post
Pre-Mission Data Preparation System
Mission Planning Systems (MPS)
Multiple Launch Rocket System
MLRS Project Office - IFCS.
MLRS Project Office – ILMS
Mod Miniature Receive Terminal
Non-Developmental Airlift Aircraft
Non-Line of Sight Project Office
Pacer Speak
Patriot Project Manager
Peace Fenghuang, AFMSS
Peace Fox VI, AFMSS
Peace Sun IX, AFMSS
Propulsion Development Systems
Quiet Knight (SOF)
RAH - 66 Comanche -- T-800 Eng
RAH - 66 Comanche Program
RAH - 66 Comanche Airframe
R/IGS - Eagle Vision/Commercial
RFMETS
Space Surveillance Network Improve
SOFPARS
SR-71 Joint Airborne Sigint Sys
SR-71 Re-activation
STINGER Product Office
Surveillance and Control SPO
T-2S Simulator For Electronic Co
T-3A Enhanced Flight Screener
TADS/PNVS
TACMS-BAT Army
THAAD Radar Product Manager
Theater Deployable Communication
Theater Missile Defense
Tri-Service Standoff Attack Missile
Utility Helicopters (Black Hawk)
Voice Processing Training System
Voice Comm Switch System
Wind Corrected Munitions Dispenser

Chapter 7

Methods Used to Analyze and Present the Survey Results

The method used to analyze any survey results depends greatly on the type and form of data collected. The three surveys entailed in this research were used to gather both factual and subjective data, in continuous, discrete, and categorical formats. Most of the analysis was accomplished using standard, well-documented statistical techniques, such as the independent samples t-test, and the paired samples t-test. These methods will not be described here, but the reader can refer to any number of texts that cover standard statistical procedures.[87] The methods used to analyze the factors involved in developing initial project schedules will be discussed in detail.

This chapter will also discuss the various methods used to present the survey results and the reasons for their use. It will identify the benefits and shortcomings of each method so the reader fully understands what is and is not presented.

---

[87] George W. Snedecor and William G. Cochran. Statistical Methods. 8th Edition. Iowa State University Press. Ames IA. 1989.

A. Types of Data Collected and Types of Questions and Scales Used

Both factual and opinion data were collected through the surveys. Factual data were collected using both continuous and categorical responses. Opinion data were collected using dichotomous, rank ordering, and interval scales.

A.1. Factual Data

Where possible, factual data were collected using continuous variables. Examples include questions about budgets, schedules, and various other factors reported as continuous variables such as dollars, months, or number of people. These responses were used as continuous variables throughout the analysis. Other types of factual data were collected using categories or dichotomous responses. These included yes/no questions and selections among a range of choices.

An example of a continuous variable question is:

Question B.1. What is this project's current estimate or actual budget expenditure, and what were the initial planned expenditures for all program expenses in each of the following program phases? Use actual or projected then-year dollars.

	CURRENT ESTIMATE	INITIAL PLAN
Pre-EMD	________ ($ million)	________ ($ million)
EMD	________ ($ million)	________ ($ million)
Production	________ ($ million)	________ ($ million)

An example of a dichotomous question is:

Question C.9. Did the Government, through its RFP or other means, specify an expected project schedule to the contractors?

❒ No. ❒ Yes.

Finally, an example of a question with a discrete set of choices is:

Question **A.5.** Which of the following categories best describes the type of system this project is developing?

❒ Aircraft (airframe and mechanical systems)	❒ Electronic system (non-aircraft)
❒ Aircraft (avionics and electronic systems)	❒ Missile or munitions
❒ Aircraft (propulsion)	❒ Software-dominated system
❒ Spacecraft or launch system	❒ Other:________________________

These questions could be answered based on facts available to the respondent.

A.2. Opinion Data

Not all the necessary information could be obtained from factual data. The other types of data desired included statements of respondents’ opinions, beliefs, and views on various aspects of a development project. Since the respondents were the individuals making most of the decisions and thus having the greatest impact on the aspects being measured, their views and opinions were significant. The actions they took and the decisions they made were based on their perception of events and the information they were provided. What the surveys measured was their interpretation of the information on which they based their decisions.

These responses were collected in several formats, including choices between two opposing responses, choices among preset categories, rank orders of a number of items, and information on an ordered scale. Examples are provided for each type of question below.

Dichotomous Answers

When it was deemed appropriate to ask respondents to choose between two opposing answers, yes/no or dichotomous questions were used. These questions asked respondents to select one answer best representing their project from two opposing statements. The answers are presented as percentage of responses, or they are used to separate groups of cases for testing of other variables. An example of a dichotomous question is:

Question A.16. From each of the following pairs of statements, please select the one from each row which **best represents** this project:

Statement A	or	Statement B
❒ This project was started as the result of the normal service planning process.		❒ This project was started at a senior leader’s direction.
❒ This project is intended to meet a **current** operational deficiency.		❒ This project in intended to meet a **future or projected** operational deficiency.

Selection of Categories

Where information could be categorized adequately, respondents were asked to select among different responses based on specific word descriptions. The resulting data were used to sort the projects into different groups to check for differences in other variables. An example is:

Question A.12. Please mark the response that best describes the scope of the technological advance in ***product*** technologies required by this project, relative to existing systems:

- ❒ Revolutionary new core technologies or concepts.
- ❒ New generation of product architecture or platform.
- ❒ Incremental improvements to an existing generation of product architecture or platform.
- ❒ Little or no change to the existing product technology.

Rank-Ordering

In some cases respondents were asked to rank-order a list of factors that may have influenced their decisions. This method was used when the order of items was important and they were few, usually four or less. These data were used to present the relative ranking of project objectives in raw format, and to categorize the projects for analysis of other variables. A sample of this type of rank question is:

Question A.13. Please rank the order of importance of the following considerations in meeting this project’s objectives (“1” indicates the item with the greatest importance in meeting this project’s objectives, “4” indicates the item with the least importance in meeting this project’s objectives):

_____ Low acquisition cost.
_____ Low operational and support cost.
_____ Short schedule to reach operational capability.
_____ Superior technical performance.

Interval Scales

For questions where the strict order was not important, or where the number of item made rankings difficult and time consuming, a seven-point interval scale was used to collect information. The seven-point scale was seen as providing sufficient distinction among factors but not overloading respondents with choices. This scale, while discrete in nature, represented a continuous and equal interval range of the impact of various factors, with one typically representing the least impact and seven representing the most impact. An example of this type of question is:

Question C.6: Please indicate the extent to which you believe the following factors helped determine the **length of the government's initial schedule** for this project:

	No Impact			Some Impact			Defining Impact
User's desired schedule	1	2	3	4	5	6	7
Service leadership desired schedule	1	2	3	4	5	6	7
Service planning process	1	2	3	4	5	6	7
Expected development funding availability	1	2	3	4	5	6	7
Expected production funding availability	1	2	3	4	5	6	7
Technology development	1	2	3	4	5	6	7
Engineering requirements	1	2	3	4	5	6	7
Manufacturing process development	1	2	3	4	5	6	7
Testing requirements	1	2	3	4	5	6	7
Support requirements	1	2	3	4	5	6	7
Dependence on another program	1	2	3	4	5	6	7
Other: ______________________	1	2	3	4	5	6	7

The information collected from these questions was analyzed to determine the relative importance of various factors influencing initial schedule development and other areas of interest. The method used to analyze the responses was employed extensively in this thesis and will be discussed in more detail.

During analysis, data from the three surveys was pooled where appropriate and where there was no significant differences among responses. Where significant differences were noted among the three surveys, the analysis discussed those differences in terms of particular questions. In general, the surveys revealed marked agreement among responses to the three surveys. What's more, no significant differences appeared among surveys completed for the same project at the Pentagon, Program Office, or contractor levels. However, the number of overlapping surveys for a given project was relatively small (8), making analysis of matched surveys statistically unsound. Thus no matching of projects among the Pentagon, Program Office, or contractor surveys was used in the analysis.

B. Methods Used to Analyze the Interval-Scale Data and to Determine the Relative Impact of Various Factors

Several methods were used to analyze the survey results, including visual comparison of raw aggregated data, comparison of the standard errors of the means, and paired samples tests. The objective was to distinguish the influence of different factors on project schedules.

Each respondent rated the various factors against the same scale. A difference in the rating of two factors by that respondent indicated a difference in the perceived impact. If a factor was systematically reported to have a larger impact than another, this was interpreted to mean that the factor has a larger impact on project schedules across the development system.

When combining individual project responses to provide a description of the overall schedule development process, one can look at the distribution of the responses to each question separately, or at the differences among ratings of each factor within each survey. Various statistical tests were used to determine if the differences among responses for factors were statistically significant. Where statistical differences existed among the distribution of responses for various factors, and the distribution of responses for each possible pair of factors, these results were interpreted to mean there was a difference across the range of projects included in the analysis. The null hypothesis was that there is no difference among various responses for the two factors, which would indicate there is no difference between the impact of the factors. The alternative hypothesis was that responses to the various factors were different, indicating a difference in the impact on initial schedules between the two factors across survey respondents. Various statistical tests were used to show that there was or was not a statistical difference between the various factors. For pairs of factors between which statistical methods cannot distinguish, those factors were interpreted to have an equal impact on the schedule development process.

B.1. Visual Inspection of Raw Aggregated Data Distributions

Before the statistical analysis was conducted, the database was visually inspected for the distribution of responses to each question. The visual inspections indicated that several of the responses had bi-modal distributions, with spikes at no impact and some impact. In many cases the data collected did not appear to follow a normal distribution, somewhat limiting the number of statistical tests that could be used.

Standard statistical measures were used during the initial screening of the data. Below are samples of the tabular and graphical data formats used to inspect the data.

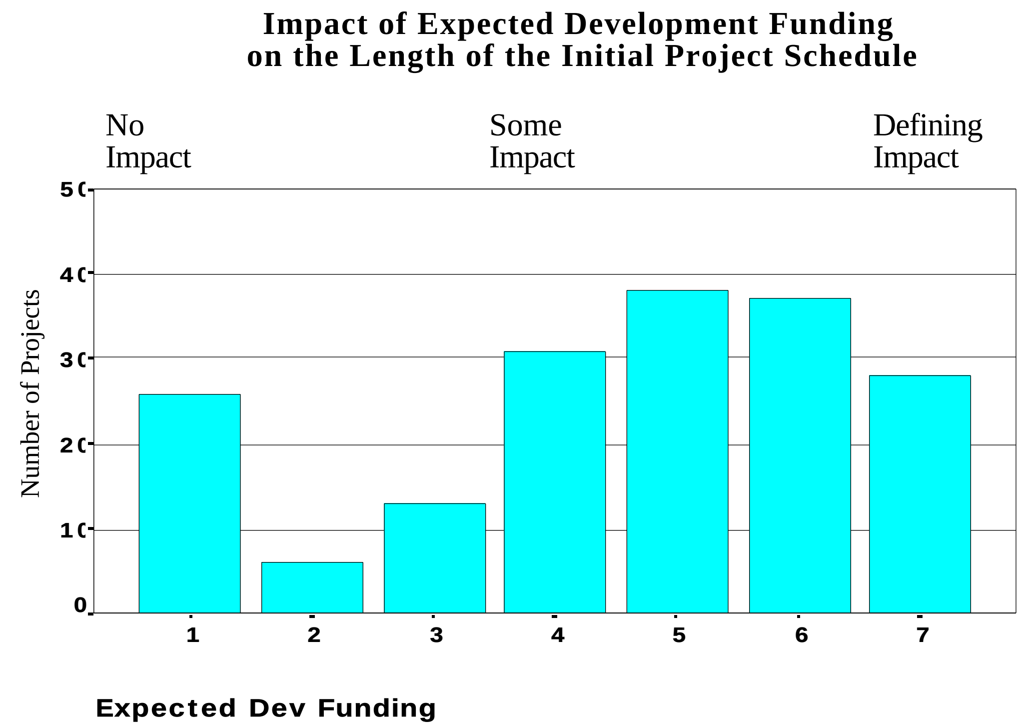
Order Asked	Description	Frequency of Responses: No Impact 1	2	3	Some Impact 4	5	6	Defining Impact 7
1	User's Desired Schedule	13	7	14	41	28	43	34
4	Expected Development Funding	26	6	13	31	38	37	28
5	Expected Production Funding	33	8	11	32	35	27	27
7	Engineering Requirements	15	18	35	46	28	24	12
9	Testing Requirements	22	22	31	42	29	25	9
2	Leadership Desired Schedule	35	15	27	31	30	22	17
6	Technology Development	32	22	30	40	21	25	8
3	Force Planning	39	17	29	30	26	22	11
11	Dependence on Another program	53	30	14	19	18	18	23
10	Support Requirements	35	45	41	27	17	10	1
8	Manufacturing Development	46	36	30	28	13	19	4

Table 7-1: Distribution of Response to the Effect of Various Factors on the Length of the Initial Project Schedule (Sorted by Median Value).

		Median	Median *	Mode	Sum	N	Quartile Range 25%	50%	75%	Mean
1	User's Desired Schedule	5	5.028	6	869	180	4	5	6	4.828
4	Expected Development Funding	5	4.841	5	809	179	3	5	6	4.520
5	Expected Production Funding	5	4.552	5	736	173	3	5	6	4.254
7	Engineering Requirements	4	3.951	4	708	178	3	4	5	3.978
2	Leadership Desired Schedule	4	3.862	1	671	177	2	4	5	3.791
9	Testing Requirements	4	3.836	4	685	180	3	4	5	3.806
6	Technology Development	4	3.571	4	637	178	2	4	5	3.579
3	Force Planning	4	3.559	1	619	174	2	4	5	3.557
11	Dependence on Another Program	3	2.886	1	590	175	1	3	5	3.371
8	Manufacturing Development	3	2.727	1	527	176	1	3	4	2.994
10	Support Requirements	3	2.709	2	508	176	2	3	4	2.886

* Calculated as if from grouped data

Table 7-2: Distribution Statistics for Responses to the Effect of Various Factors on the Length of the Initial Project Schedule.



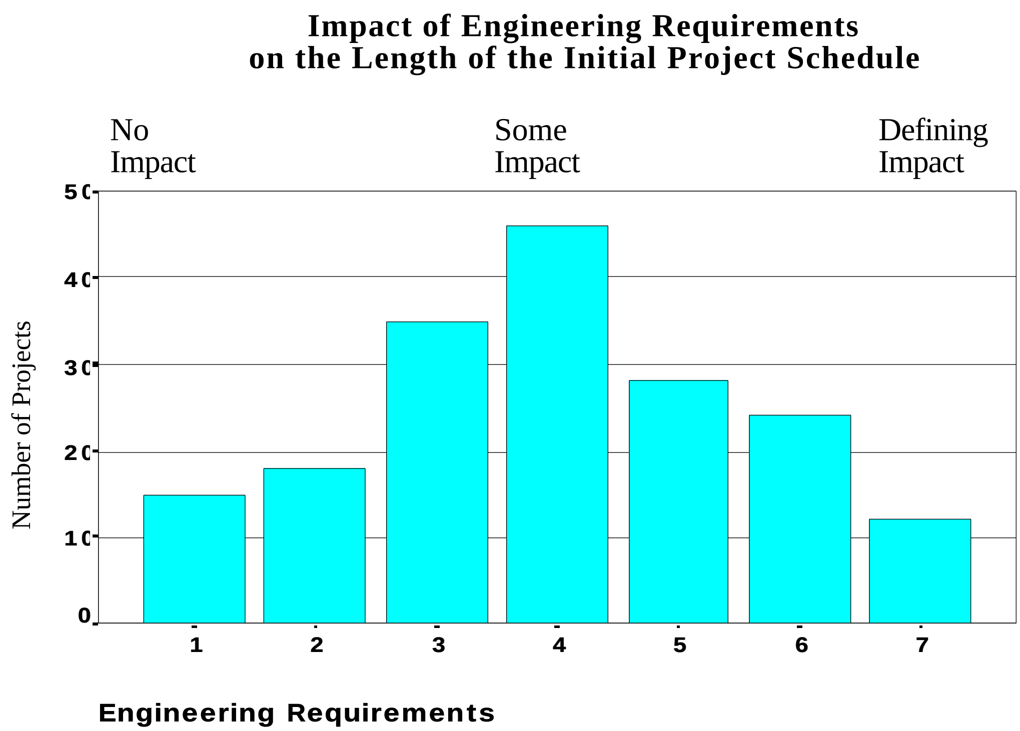


Figure 7-1: Distribution of Responses for Impact of Expected Development Funding and Engineering Requirements on the Length of the Initial Project Schedule.

One then can compare the means and the standard deviations to determine which factors were rated higher than the others. However, comparisons based on the mean and standard deviations are flawed, as they assume normal or near-normal distributions, which were not apparent in some cases. What's more, comparison of the means, while illustrative and helpful, may not reveal significant differences that may exist in the data, as such comparisons are less efficient from a statistical standpoint than other methods available. Comparison of the standard error of the mean and various paired sample methods allows the survey data to be used on a project-by-project basis, as opposed to aggregate data only.

B.2. Comparison of the Sample Means for Different Factors

The mean of the responses to a given question provided a view of the average response of those surveyed across the projects. This mean estimated the average of the entire population within the bounds of standard error. Averaging across a wide array of projects with different characteristics may hide important variations among those projects. Since the objective is to describe the system as a whole, the response averages have some utility. However, they do not indicate how the various factors affected an individual project.

During the analysis, the survey responses were subdivided into an array of categories, with the answers to various questions used to look for systematic differences among the categories. Those included the cost of a project, the type of project, the type of contract, the development phase of the project, and the amount of technological advance. The rank-order of the average responses to most questions was found to be consistent or nearly consistent irrespective of the category or type of project. The analysis of the subsets of projects based on their characteristics is discussed in the analysis of individual questions.

To analyze the data, the mean responses and the standard error of the mean were determined using the survey results. Even if the distribution of the raw responses to a question was not normal, the large number of projects obtained through the surveys indicated that the sampling distribution of the mean will be near normal in shape, and will allow the use of the standard t-test to compare the distribution of the sample mean of responses.

The sample mean, and the sample standard deviation and standard error of the mean, are calculated with the equations below.

Sample Mean $= \underline{X} = \sum (X_i/N)$ **Equation 7-1**

Where

N is the number of survey responses

X_i is the response for each individual project/survey

Sample Standard Deviation = $S = (\sum (X_i - \underline{X})^2/(N-1))^{1/2}$ **Equation 7-2**

Standard Error of the Mean = $S_{\underline{x}} = S/(N)^{1/2}$ **Equation 7-3**

The results for the example used earlier are:

Expected Development Funding

$\underline{X} = 4.52$
$S = 1.93$
$N = 179$

Standard Error of the Mean = 0.144

Engineering Requirements

$\underline{X} = 3.98$
$S = 1.64$
$N = 178$

Standard Error of the Mean = 0.123

Plotting the means of the responses--and the standard error of the means--for the impact of various factors on initial development schedule allows the average of the responses and the expected errors to be viewed graphically.

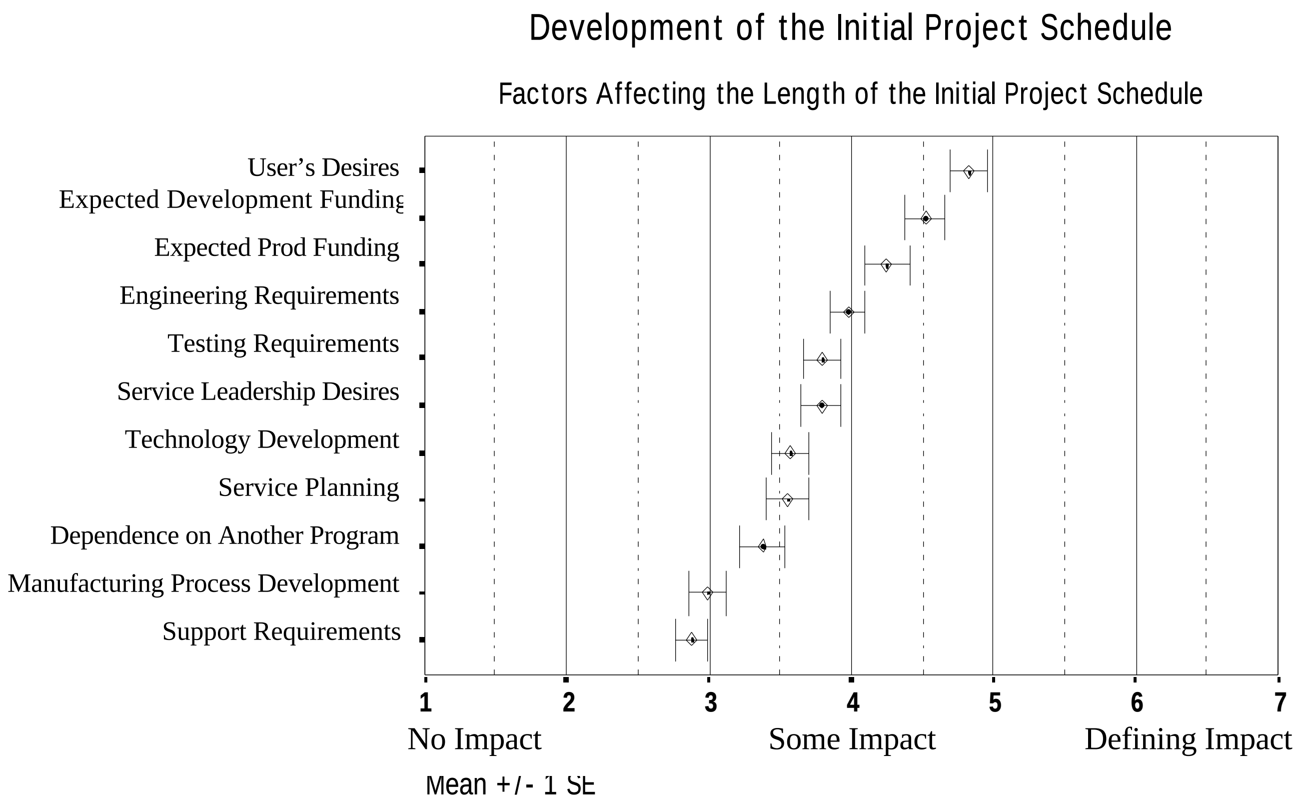


Figure 7-2: The Average and Standard Error of the Mean for Responses to the Impact of Various Factors on the Length Initial Project Schedule.

The unpaired sample t test can be used to compare the mean of two factors. The null hypothesis is that there is no difference between the mean responses to the impact of two scheduling factors. The following equation is used to calculate the t value for a comparison of the means of two independent samples tests.

$$t\_ = (\underline{X}_1 - \underline{X}_2)/(S_1^2/N_1 + S_2^2/N_2)^{1/2}$$ **Equation 7-4**[88]

where: $\underline{X}_1$ is the mean of the responses for the first factor

$\underline{X}_2$ is the mean of the responses for the second factor

S_1 is the standard deviation for the responses to the first factor

S_2 is the standard deviation for the responses to the second factor

[88] George W. Snedecor and William G. Cochran. Statistical Methods. Analysis of Independent Samples when $\sigma_1 \neq \sigma_2$. Pg. 97.

N_1 and N_2 are the number of projects surveyed

The degrees of freedom for the test are approximated to allow the ordinary t distribution tables to be used. The approximation for the number of degrees of freedom is given by:

$$\mathbf{v\_ = (\upsilon_1 + \upsilon_2)^2 / (\upsilon_1^2 / v_1 + \upsilon_2^2 / v_2)}$$ **Equation 7-5**[89]

where: $\upsilon_1 = S_1^{\ 2}/n_1$

$\upsilon_2 = S_2^{\ 2}/n_2$

$v_1 = n_1 - 1$

$v_2 = n_2 - 1$

The approximate degrees of freedom for t' are given by v', which is rounded down to the nearest integer so that standard t tables can be used.[90]

Using the example discussed:

$t' = (4.52 - 3.98)/((1.93^2/179)+(1.64^2/178))^{1/2} = 2.849$

$v' = ((1.93^2/179)+(1.64^2/178))^2 / ((1.93^2/179)^2/(178)+ (1.64^2/178)^2/(177)) = 346.58$

Approximate Degrees of Freedom = 346

The null hypothesis--that there is no difference between the two samples--can be rejected based on the value of t' and the number of degrees of freedom at difference levels of confidence. With the sufficiently large sample sizes captured in the research, t' can be estimated by t, and either calculated from the normal deviate or looked up in any standard statistics reference book. The 5 percent and the 0.5 percent level of confidence for t' is:

$t'_{0.05}$ = 5% confidence level = 1.96 (346 df)

$t'_{0.005}$ = 0.5% confidence level = 2.807 (346 df)[91]

---

[89] George W. Snedecor and William G. Cochran. Statistical Methods. Analysis of Independent Samples when $\sigma_1 \neq \sigma_2$. Pg. 97.

[90] Snedecor and Cochran. Statistical Methods. Analysis of Independent Samples when $\sigma_1 \neq \sigma_2$. Pg. 97

[91] George W. Snedecor and William G. Cochran. Statistical Methods. Analysis of Independent Samples when $\sigma_1 \neq \sigma_2$. Pg. 466.

Using the t distribution, the probability that the average of the two samples will be equal is 0.5 percent--well below the 5 percent typically required for demonstrating statistical significance. More powerful statistical methods are available that use the survey information on a project-by-project basis.

B.3. Paired-Samples Statistical Methods

Analyzing the multiple-response questions using paired-sample statistical methods allows the relative importance of factors to be compared on a project-by-project basis. The distribution of responses can then be evaluated to determine if there is a statistical difference between them. The pairing of the data within a single project ensures that each factor is affected by the same events and interpreted by the same person. Using the information in this manner removes the effects of non-related factors, as each project response is compared only with responses from the same project. By using the paired responses from each project separately, it is possible to eliminate differences that result from the specific nature of the projects, or from respondents' different interpretations of the scale.

When comparing two factors, the response for one factor is subtracted from the response for the other factor. If there is no systematic difference between the two factors, the distribution difference of the paired responses should be centered on no difference. Continuing with the earlier example, the reported differences between the impact of the expected development funding and the engineering requirements is shown in Figure 7-5. A negative number indicates that the engineering requirements were rated as having a larger impact on the length of the initial project schedule, and a positive response indicates that expected development funding had a greater impact on that project. A zero response indicates that the respondent rated them as equally important. The numbers on the horizontal axis indicate the difference between the two responses by a single respondent. The numbers on the vertical axis represent the number of respondents reporting the same difference between the two responses.

The data are interpreted based on the assumption that the larger the difference between the reported responses, the larger the differences in the impact of the two factors. For example, if a respondent reported that the engineering requirements had no impact (and thus rated them a 1) and chose funding availability as the defining impact (thus rating it a 7), the difference between the two responses would be 6. This would indicate a larger difference than in the case of someone who awarded the engineering requirements a 5 and the funding availability a 6, as the difference between those two values would be 1. If the factors are equally important or there are no systematic differences between them, there should be an equal number of responses indicating a positive and negative difference. The existence of such a difference can be tested using various paired-sample statistical methods.

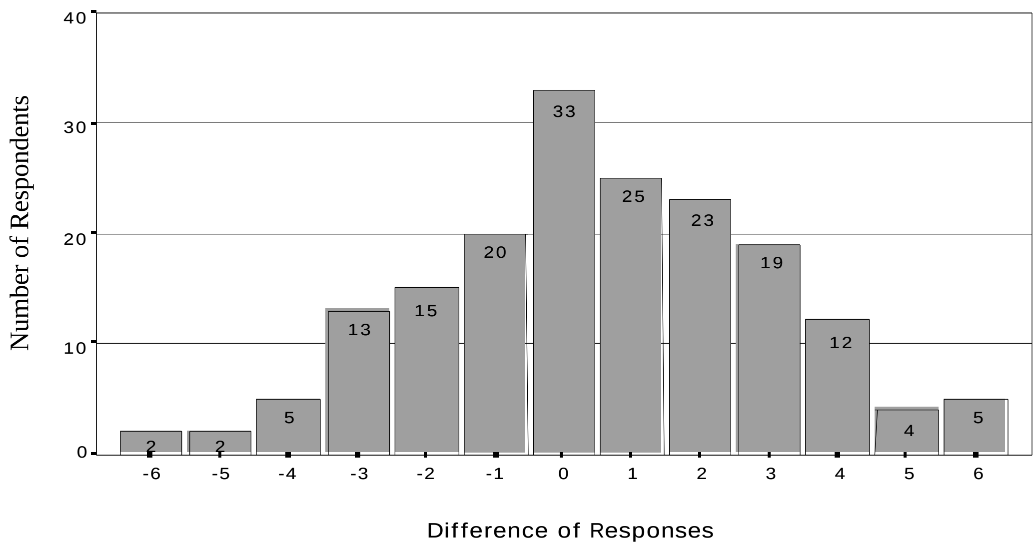


Figure 7-3: Distribution of Differences between the Reported Impact of Development Funding and Engineering Requirements on the Length of the Initial Project Schedule.

Three primary paired-comparison methods can be used with the type of scale data collected by the surveys. These include the paired-samples t-test corrected for continuity, the non-parametric sign test, and Wilcoxon signed-rank test. Parametric tests make certain assumptions about the distributions of the data, such as that it is continuous and normally distributed. This could not be assured for this analysis, so the parametric tests were not used.[92] Non-parametric tests do not require such assumptions. Parametric tests are usually more powerful than the non-parametric tests, as they are less likely to indicate a significant difference when there is not one, and they are less likely to indicate that there is no significant difference when there is one.

Sign Test

The sign test is a relatively simple test that looks solely at the direction of the differences between two matched responses. It does not measure the magnitude of the difference. If there is no systematic difference in the responses for the two factors, there should be roughly an equal number of cases where one factor is rated higher than the other. The null hypothesis is that the two distributions are equal, and that each paired difference has an equal chance of being positive or negative. A large disparity in the number of positive and negative differences would indicate that the distributions are not equal, and that the null hypothesis can be rejected for the two responses. This test is accomplished for every possible pair of responses (the test ignores ties). The results of the sign test for expected development funding and engineering requirements are provided below as an example.

In 88 cases, responses rated expected development funding as having more impact than engineering requirements on the length of initial project schedule. The engineering requirements were rated higher in 57 cases, and in 33 cases the factors were rated equally.

Example Sign Test

Expected Development Funding Rated Larger	88 + Diffs
Engineering Requirements Rated Larger	57 - Diffs
Rated as Equal	33 Ties
Number of Cases	178
Number of Non-Tied Cases	145

The normal deviate corrected for continuity is calculated by:

$$\mathbf{Z_c = (|2r-n|-1)/n} \qquad \textbf{Equation 7-6}$$[93]

Where r is the number of positive or negative values and n is equal to the number of non-tied samples. For example:

$$Z_c = (|2*88-145|-1)/145^{1/2} = 2.4914$$

The two-tailed significance can be calculated from the cumulative normal frequency distribution, or it can be obtained--as it was in this case--from a statistics table for normal distribution.[94] The probability that the two factors are actually equal and that the result is a statistical fluke is 0.0180.

2-Tailed P = 0.0180

The sign test is not as efficient in determining differences between populations as tests that use the magnitude of the difference between responses. The other non-parametric test, the

[92] The results using the parametric and non-parametric tests were similar where checked.

[93] George w. Snedecor and William G. Cochran. Statistical Methods. 8th Edition. Iowa State University Press. Ames, Iowa. 1989. Pg. 139.

[94] George w. Snedecor and William G. Cochran. Statistical Methods. 8th Edition. Iowa State University Press. Ames, Iowa. 1989. Pg 464.

Wilcoxon signed-rank test, uses the magnitude as well as the sign of the difference, and so is considered more decisive.

Wilcoxon Signed-Rank Test

Because the Wilcoxon signed-rank test is a non-parametric test, it does not require the assumption of a normal distribution. The use of this test assumes that the larger the difference in ratings between two factors, the larger the differences in the factors' effects.

In the Wilcoxon signed-rank test, the absolute values of the differences between the matched pairs of data are rank-ordered from 1 to n, with the smallest difference as 1. For the responses with equal differences, the average of the ranks is used. The rankings associated with the positive differences and the rankings associated with the negative differences are then summed separately. Responses with no difference between the factors are not included. The smaller of the two sums is then used to calculate the probability. For large numbers of pairs the normal deviate, corrected for continuity, is given by:

$$\mathbf{Z_c = (\mu - T - 0.5)/\sigma} \qquad \textbf{Equation 7-7}$$ [95]

Where

$\sigma = ((2n+1)\_/6)^{1/2}$

$\mu = n(n+1)/4$

T = smaller of the sum of the positive and negative ranks

n = number of pairs

The probability that there is no difference between the two factors can be determined using the two-tailed significance obtained from the cumulative normal frequency distribution. For a normal distribution, the null hypothesis--that the two factors are rated equal--can be rejected at the 0.05 level. $Z_c > 1.96$ equates to a probability of 0.05, which signifies rejection of the null hypothesis and indicates that the two factors are actually rated differently.

An example using the Wilcoxon signed-rank T test to measure the impact of expected development funding and engineering requirements is shown below. The table on the next page shows the responses ordered by the absolute value of the differences between the two factors. A positive value indicates that expected development funding was rated as having a larger impact, and a negative value indicates that engineering requirements were rated as having a larger impact. The responses are then ranked from 1 to 145 by the absolute value of the differences. The adjusted

[95] George w. Snedecor and William G. Cochran. Statistical Methods. 8th Edition. Iowa State University Press. Ames, Iowa. 1989. Pg 141.

rankings account for responses with equal differences by taking the average of the rank of the responses as illustrated in Table 7-3 below.

Difference	Absolute Value of Difference	Raw Ranking	Adjusted Ranking
-1	1	1	23
-1	1	2	23
-1	1	3	23
1	1	4	23
1	1	5	23
1	1	6	23
1	1	7	23
1	1	8	23
-1	1	9	23
1	1	10	23
-1	1	11	23
-1	1	12	23
1	1	13	23
1	1	14	23
1	1	15	23
1	1	16	23
-1	1	17	23
-1	1	18	23
1	1	19	23
1	1	20	23
-1	1	21	23
-1	1	22	23
-1	1	23	23
-1	1	24	23
-1	1	25	23
1	1	26	23
1	1	27	23
-1	1	28	23
1	1	29	23
1	1	30	23
1	1	31	23
1	1	32	23
1	1	33	23
-1	1	34	23
-1	1	35	23
1	1	36	23
-1	1	37	23
1	1	38	23
1	1	39	23
-1	1	40	23
1	1	41	23
1	1	42	23
1	1	43	23
-1	1	44	23
-1	1	45	23
-2	2	46	64.5
2	2	47	64.5
2	2	48	64.5
2	2	49	64.5
2	2	50	64.5
2	2	51	64.5
2	2	52	64.5
-2	2	53	64.5
2	2	54	64.5
-2	2	55	64.5
2	2	56	64.5
-2	2	57	64.5
-2	2	58	64.5
2	2	59	64.5
2	2	60	64.5
2	2	61	64.5
2	2	62	64.5
2	2	63	64.5
2	2	64	64.5
-2	2	65	64.5
2	2	66	64.5
-2	2	67	64.5
2	2	68	64.5
2	2	69	64.5
2	2	70	64.5
-2	2	71	64.5
-2	2	72	64.5
-2	2	73	64.5
-2	2	74	64.5
-2	2	75	64.5
2	2	76	64.5
2	2	77	64.5
2	2	78	64.5
-2	2	79	64.5
-2	2	80	64.5
2	2	81	64.5
2	2	82	64.5
-2	2	83	64.5
3	3	84	99.5
3	3	85	99.5
-3	3	86	99.5
-3	3	87	99.5
3	3	88	99.5
-3	3	89	99.5
-3	3	90	99.5
3	3	91	99.5
-3	3	92	99.5
-3	3	93	99.5
3	3	94	99.5
3	3	95	99.5
-3	3	96	99.5
3	3	97	99.5
3	3	98	99.5
3	3	99	99.5
3	3	100	99.5
3	3	101	99.5
3	3	102	99.5
-3	3	103	99.5
-3	3	104	99.5
-3	3	105	99.5
-3	3	106	99.5
3	3	107	99.5
3	3	108	99.5
3	3	109	99.5
3	3	110	99.5
3	3	111	99.5
-3	3	112	99.5
-3	3	113	99.5
3	3	114	99.5
3	3	115	99.5
-4	4	116	128
4	4	117	128
4	4	118	128
4	4	119	128
4	4	120	128
4	4	121	128
-4	4	122	128
4	4	123	128
-4	4	124	128
4	4	125	128
-4	4	126	128
4	4	127	128
4	4	128	128
4	4	129	128
4	4	130	128
4	4	131	128
-4	4	132	128
5	5	133	135.5
5	5	134	135.5
5	5	135	135.5
-5	5	136	135.5
-5	5	137	135.5
5	5	138	135.5
-6	6	139	142
6	6	140	142
6	6	141	142
-6	6	142	142
6	6	143	142
6	6	144	142
6	6	145	142

Table 7-3: Ranking Used for Wilcoxon Signed-Rank Test on the Impact of Expected Development Funding and Engineering Requirements on Length of Initial Project Schedule (33 Responses with No Difference Are Not Included).

The sum of the ranking for responses rating expected development funding higher is 6737, and the sum of the ranking for those that rate engineering requirements higher is 3916.

Using the minimum of the two sums as specified by the Wilcoxon method,

n = number of pairs = 145

μ= n(n+1)/4 = 145(145+1)/4 = 5,292.5

σ =((2n+1) _/6)$^{1/2}$ = ((2*145+1)*5,292.5/6) $^{1/2}$ = 506.64

T = smaller of the sum of the positive and negative ranks = 3,916

$$\mathbf{Z_c = (\mu - T - 0.5)/\sigma = (5292.5 - 3916 - 0.5)/506.64 = 2.7159}$$

The probability that the null hypothesis is true and that there is no difference between the two factors is determined by the two-tailed significance obtained from the cumulative normal frequency distribution. For example, the probability that the two factors are actually equal is 0.0033.

2-Tailed P = 0.0033

This is significantly beyond the 0.05 level typically used to show statistical significance. For the analysis used in this survey, the statistical tests were conducted using the SPSS statistical data software package produced by SPSS, Inc.[96]

A comparison of results from the three statistical tests showed little difference among factors when they were approaching statistically significant levels. For the analysis, the signed-rank test was selected, as it was seen as the most efficient test that did not rely on the assumption of a normal distribution of the data, which could not be guaranteed. The signed-rank test was used for analysis except where specifically noted.

B.4. Development of Statistical Groups of Factors

The paired-sample statistics tests indicated that there was or was not a statistical difference between any two factors. Because there were typically many factors rated for each of many questions, presenting the results as a factor-by-factor comparison for each pair of factors was determined not to be impractical. To provide a method for presenting and discussing the data at a higher level, factors that could be distinguished with statistical methods were separated into different statistical groups, and factors that could not be distinguished from each other were grouped together. The resulting groups could then be used to discuss the impact of the different factors at a higher level.

The different statistical groups were determined by first developing a factor matrix indicating the probability that each possible pair of factors was equivalent. This matrix was based on the results of the Wilcoxon signed-rank test, and its initial order was determined by the average of the responses. A visual inspection of each matrix looked for factors that appeared out of order based on the probabilities. In almost all cases, ordering the factors by their mean values proved adequate to determine the statistical groups, as described below.

The statistical groups were determined by visually inspecting the factor matrix and identifying the groups of factors that were statistically different from other groups of factors. This was done by first identifying statistical differences between adjacent factors within the matrix, and then checking to ensure there were statistical differences with other non-adjacent factors. A minimum of 85 percent confidence level ($P = 0.15$) was used to indicate statistical significance between adjacent factors. The relatively low level was used because of the large number of factors and the difficulty of separating adjacent factors. Thus appropriate caution should be used when making comparisons between adjacent factors across the statistical groups. The differences between non-adjacent factors across statistical groups are typically at much higher levels of statistical significance than the 0.15 level. In some cases, the 0.15 level was not met, but in the judgment of the researcher the significant difference between close but non-adjacent factors indicated that the factors should be in different groups. The few times this occurrs, a dashed line signifies that the adjacent factors are not statistically different but that the other factors are. Generally, adjacent factors within the same statistical grouping cannot be separated with confidence based on the data obtained through the surveys. However, factors in one statistical grouping can be separated statistically from those in other groupings.

The factor matrix and the statistical groups for factors affecting the length of a project's initial schedule are shown in Figure 7-4 below.

[96] SPSS 6.1. SPSS Inc. 444 N. Michigan Ave, Chicago IL 60611.

	Users Desired Schedule	Expected Develop Funding	Expected Product Funding	Engineering Requirement	Testing Requirements	Leader Desired Schedule	Technology Development	Force Planning	Dependence on Another Program	Manufacturing Development	Support Requirements	Group
	1	4	5	7	9	2	6	3	11	8	10	
	4.83	4.52	4.25	3.98	3.81	3.79	3.58	3.56	3.37	2.99	2.89	
User's Desired Schedule	**1**	0.23	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**1**
Expected Development Funding	0.23	**1**	0.15	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**1**
Expected Production Funding	0.01	0.15	**2**	0.12	0.01	0.06	0.00	0.00	0.00	0.00	0.00	**2**
Engineering Requirements	0.00	0.01	0.12	**3**	0.17	0.36	0.00	0.05	0.01	0.00	0.00	**3**
Testing Requirements	0.00	0.00	0.01	0.17	**3**	0.90	0.19	0.39	0.03	0.00	0.00	**3**
Leadership Desired Schedule	0.00	0.00	0.06	0.36	0.90	**3**	0.18	0.10	0.03	0.00	0.00	**3**
Technology Development	0.00	0.00	0.00	0.00	0.19	0.18	**3**	0.87	0.32	0.00	0.00	**3**
Force Planning	0.00	0.00	0.00	0.05	0.39	0.10	0.87	**3**	0.25	0.00	0.00	**3**
Depend on Another Programs	0.00	0.00	0.00	0.01	0.03	0.03	0.32	0.25	**3**	0.11	0.01	**3**
Manufacturing Development	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	**4**	0.37	**4**
Support Requirements	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.37	**4**	**4**

* The significant difference determined by the Wilcoxon Rank-Sign Test

Figure 7-4: Illustration of Statistical Grouping Method Used in Analyzing Data for Factors Determining Length of Initial Project Schedule.

C. Presentation of the Data

Throughout the thesis, several methods, each with its limitations, are used to present the data. The major questions in determining how to best present the data were the amount of data available and how to make the information presentable and understandable without losing the nuances and meaning contained in the data. Large matrices of the raw number of responses in different categories were unlikely to adequately convey the meaning of the results. Throughout the analysis chapters, when there was any question as to whether to include a chart or graph that might aid the reader in understanding the analysis, the chart was included. In the summary chapters, much of this detailed information is omitted and the reader is referred to the earlier chapters.

Figure 7-6 shows the main format used throughout the thesis to present the results. It combines several types of information. First, the various factors are plotted by their mean values. The standard error is plotted about the mean based on the variance in the data. Superimposed on this are the statistical groups, as determined by the Wilcoxon signed-rank test. This chart represents many compromises, but was determined to be the most acceptable, meaningful, and understandable method for presenting the large amounts of data collected.

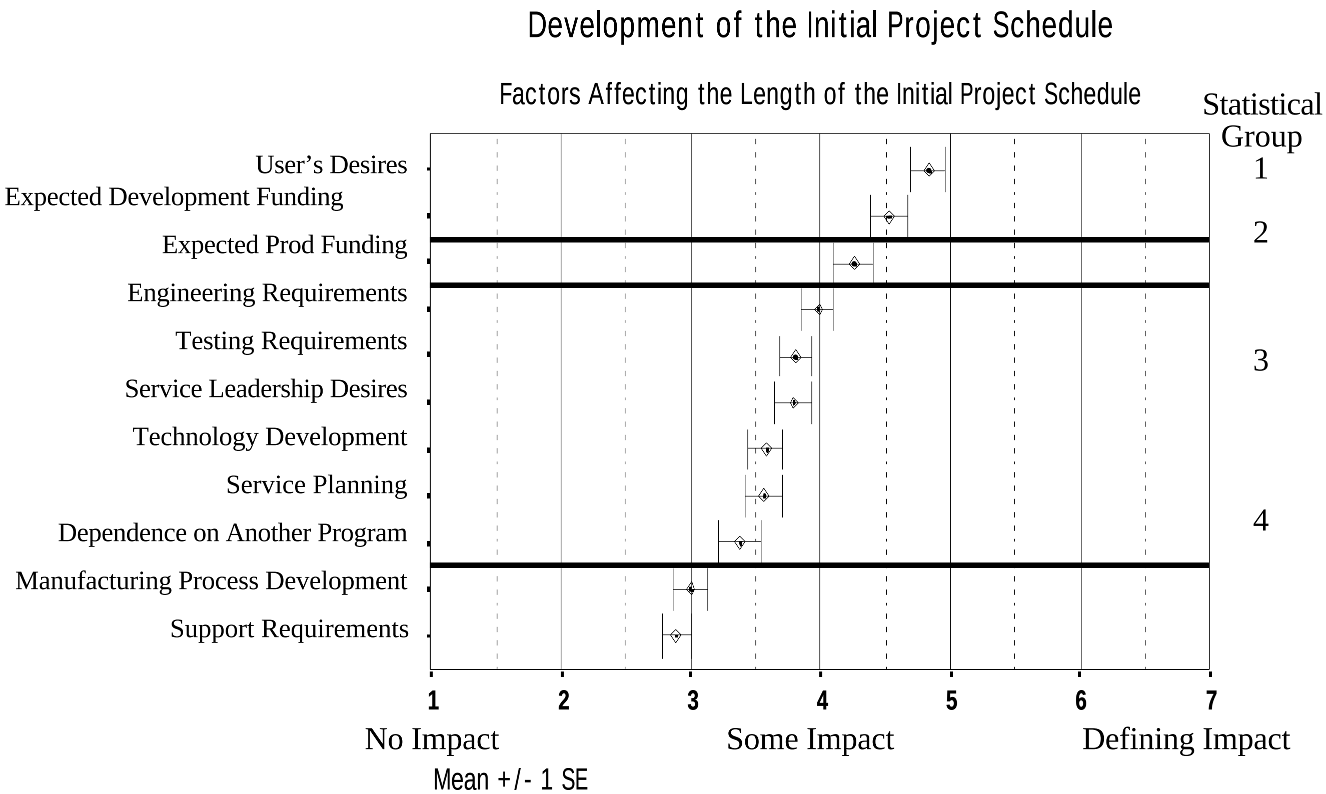


Figure 7-5: Example of a Statistical-Grouping Chart Overlaid on Average Responses and Standard Errors.

Other types of charts used to present the data include the distribution of raw responses, and displays of differences between two factors. Charts showing the latter are used sparingly, as they show the difference between only two factors at a time. Displaying pairs of charts for all interested pairs of responses would be prohibitive.

These types of charts are intended to convey the thesis message clearly to a wide range of audiences. Each chart loses some information contained in the data, and thus caution must be taken in interpreting the charts.

Chapter Summary

Throughout the surveys various types of information were collected. To analyze and present the results of the surveys, accepted statistical methods have been used. To analyze the interval scale data, the Wilcoxon Signed-Rank test was selected because, as a non-parametric statistical test, it did not rely on assumptions of normal distributions and was considered more powerful in determining statistical differences than the sign test. This method is used to compare responses within each individual survey and then to look at the distribution of the differences across all surveys. From this statistical groups for the different variables were established and a graphical method of presentation was introduced.

Part 3

The Development of a Project's Initial Schedule and Its Impacts: Survey Results and Analysis

Part 3: Overview

Part 3 describes the processes used to develop, contract, and execute project schedules based on the 317 surveys received. Chapter 8 describes the development of a project's initial schedule by analyzing the survey results. Chapter 9 documents the effects of the initial project's schedule on the contracting phase. It shows that the initial schedule has the dominant impact on contractors' proposed schedules and the resulting contracted schedules. Chapter 10 identifies schedule-related incentives for users, the Pentagon, the Program Offices, and defense contractors during the development phase. Chapter 11 highlights the effects of a project's initial schedule and the subsequent contracted schedule on the actual development schedule. It compares the project's achieved schedule with the planned schedule. Part 3 provides the foundation from which Part 4 draws conclusions and makes specific policy recommendations.

Chapter 8

Development of a Project's Initial Schedule

The development of a project's initial schedule occurs early in the acquisition planning phase and prior to project approval. Once established, the project's initial schedule forms a basis for the rest of the acquisition planning. As will be shown in following chapters, the initial project schedule plays a central role in the time used to develop new products and systems.

This chapter presents the results of the three surveys described in Chapter 6 as they pertain to development of a project's initial schedule. The areas evaluated include the user's desired schedule, the priority assigned to a project's schedule, the factors that determine a project's starting date, the organizations involved in developing a project's schedule, and the factors that influence the length of a project's schedule. Also evaluated are information and tools used to develop a project's schedule.

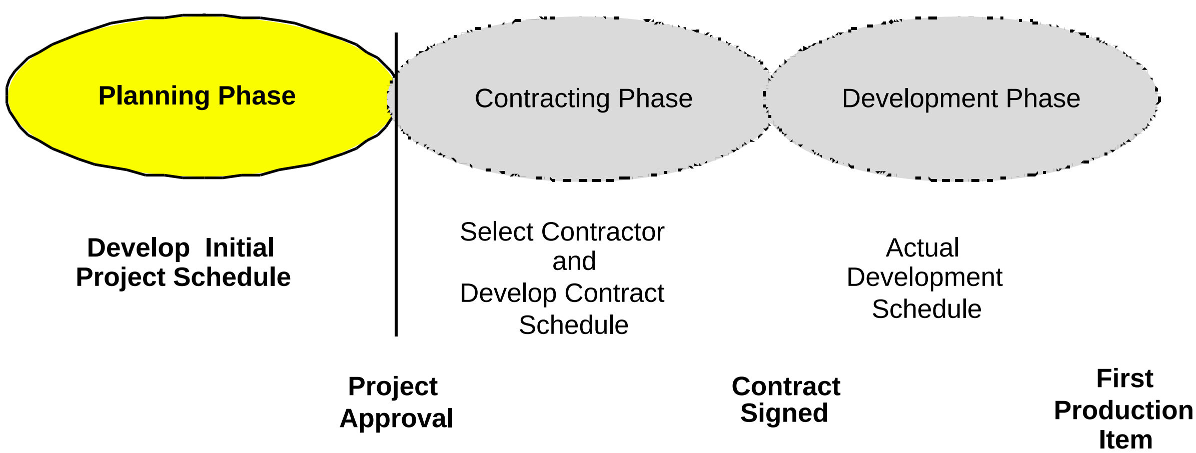


Figure 8-1: A Project's Initial Schedule, as Developed During the Project's Planning Phase.

A. When the User Desires a Project

When establishing a project's initial schedule, a primary consideration is when the user desires the system. The Pentagon survey asked program element monitors and Pentagon action officers the date by which users wanted the system and whether it was meant to meet a current or a future operational deficiency. The respondents indicated that 80 percent of users desired systems "as soon as possible," with 20 percent listing a specific date. Respondents also referred to items such as the need to integrate the system with others in development, launch schedule dates, and projected emerging threats as determining the desired date.

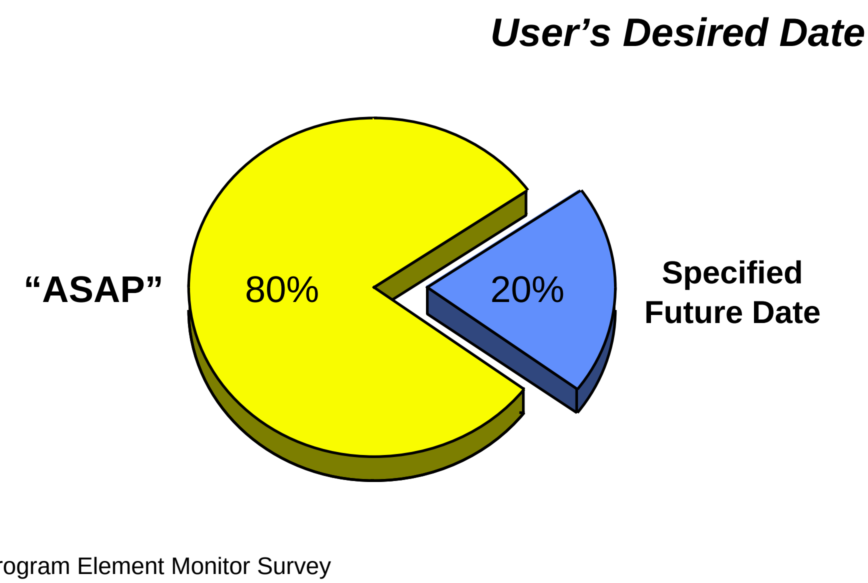


Figure 8-2: User's Desired Date of First Production Item, as Reported by Program Element Monitors (Number of Projects = 62).

Seventy percent of respondents indicated that the system was intended to meet a current operational deficiency, while 30 percent indicated that the system was intended to meet a future or projected need.

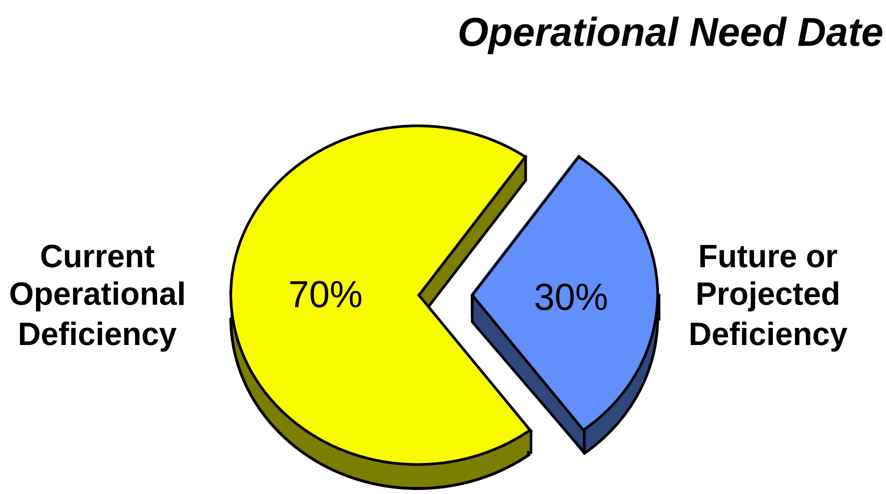


Figure 8-3: Operational Need Date for a System in Development, as Reported by Program Element Monitors (Number of Projects = 62).

The responses indicated that for most development efforts, the longer the time required to develop the products, the longer a need would go unfilled. A project schedule may also depend on the priority users give to a project. Both the Program Office and the Pentagon surveys asked respondents to indicate the priority assigned by the user commands, on a scale of 1 to 7. Thirty-one percent—or 65 of 209 respondents--indicated that their project was the highest priority. Over 60 percent selected one of the two highest responses. Only 27 percent indicated that their project was average or lower among the user's priorities.

Based on the expressed need, users' desired date of "as soon as possible," and the reported high-priority users placed on projects, a short development schedule would seem to be a significant priority. However, that does not appear to be the case.

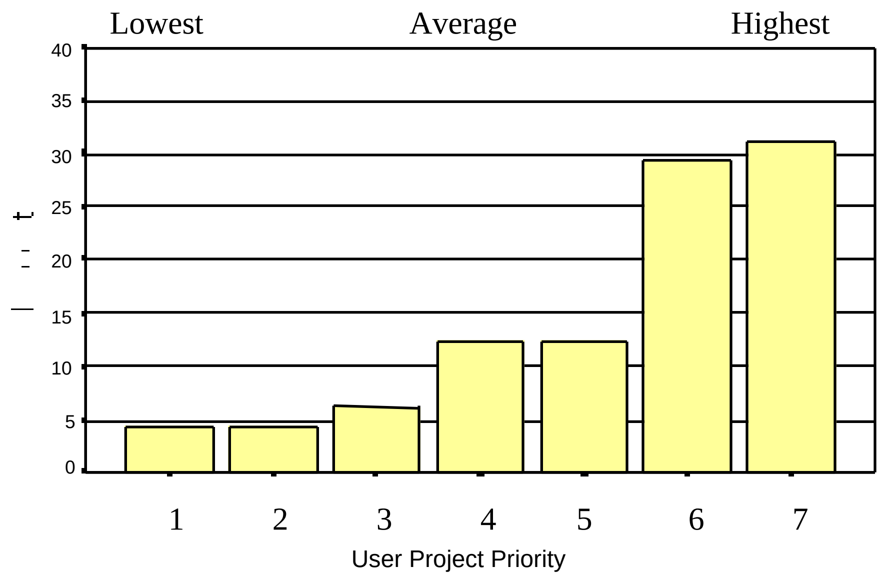


Figure 8-4: Project Priority for the User of a System (Program Office and Pentagon Surveys; Number of Projects = 209).

B. Priority of Schedule in Development Projects

To evaluate the priority assigned to short schedules in the program planning phase, the Program Office and the Pentagon surveys asked respondents to rank four project priorities: low acquisition cost, low operational and support costs, short schedule to operational capability, and superior technical performance. Superior technical performance was most often rated as a project's highest priority. Low acquisition cost was most often rated as a project's second priority. Low operational cost was most often rated as a project's third priority. Shortened schedule was most often rated as a project's fourth--or lowest--priority.

Figure 8-6 shows the number of respondents rating each objective first, second, third, or fourth. Among 208 projects, superior performance was rated as the first objective in 93 projects, low acquisition cost was rated second in 71 projects, low operating cost was rated third in 75 projects, and short schedule was rated the lowest objective in 78 projects. No significant differences were noted between the Program Office and Pentagon surveys.

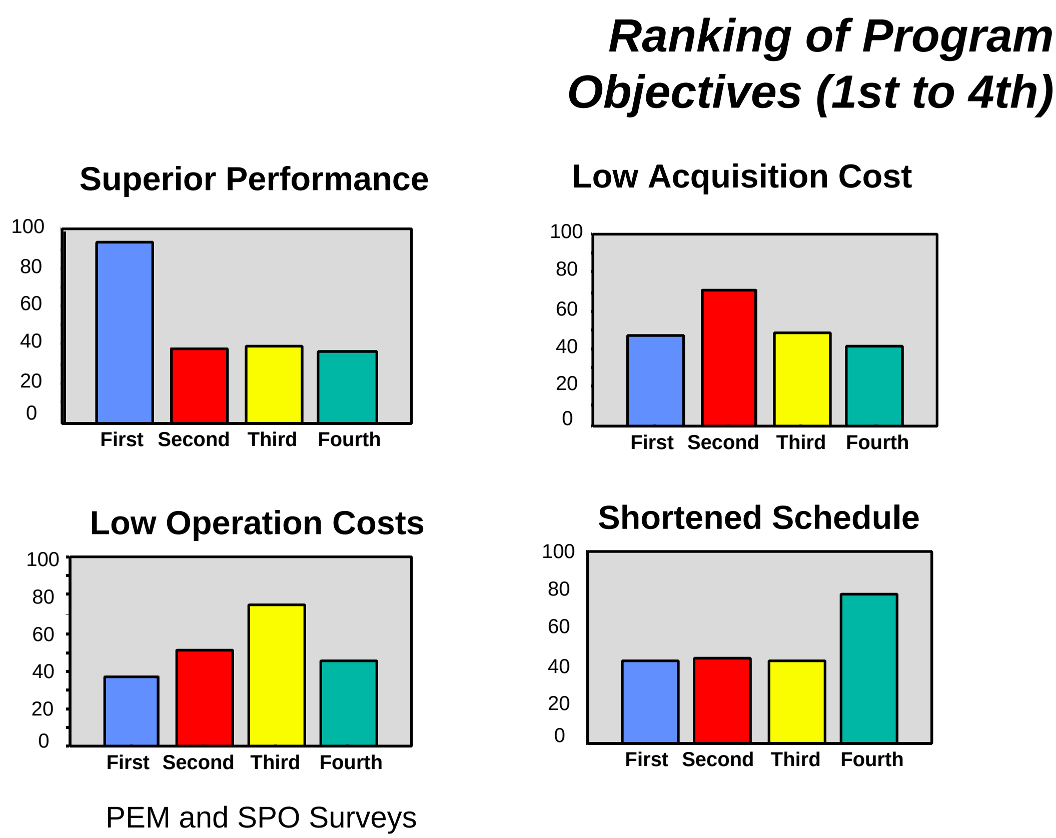


Figure 8-5: Ranking of Project Objectives by Program Managers and Program Element Monitors (Program Office and Pentagon Surveys; Number of Projects = 208).

Comparing the responses on a survey-by-survey basis using the paired-samples sign test indicates very significant differences among the different objectives. Superior performance rated statistically higher than all other objectives, with a confidence level of over 99 percent. Superior performance rated higher than shortened schedule, with a confidence level of 99.99 percent. Low acquisition cost rated higher than shortened schedules, with a confidence level of 97.5 percent. Low operating cost rated higher than shortened schedule, but with a confidence level of only 91 percent. Table 8-1 shows the statistical significance of the differences among the various project objectives.

Program Objective Significance Table

	Mode Rank	Perform	Acq Cost	Ops Cost	Schedule
Superior Performance	1st	X			
Low Acquisition Cost	2nd	.008	X		
Low Operational Cost	3rd	<.001	.024	X	
Shortened Schedule	4th	<.0001	.025	.09	X

Table 8-1: Significance of the Differences Among Project Objectives Using the Non-Parametric Paired-Samples Sign Test (Program Office and Pentagon Surveys; Number of Projects = 209).

Comparing short project schedules with other objectives does not completely reveal the importance of development time, but does indicate its relative position. To determine the importance of short schedules, the Pentagon and Program Office surveys asked to what extent a short acquisition cycle was an important part of a project's overall objectives. Among the 206 respondents, less than 15 percent indicated that a quick acquisition cycle was "very important." One-third of the respondents indicated that short acquisition time was a significant priority by selecting one of the two highest categories. Over half the respondents indicated that it was a "somewhat important" or "not important" objective.

The low priority assigned to schedule is consistent with the finding that only 27 percent of projects are considered "fast track"-- having shorter-than-normal planned development times. Seventy-three percent are not considered "fast track," and do not attempt to shorten the normal development schedule.

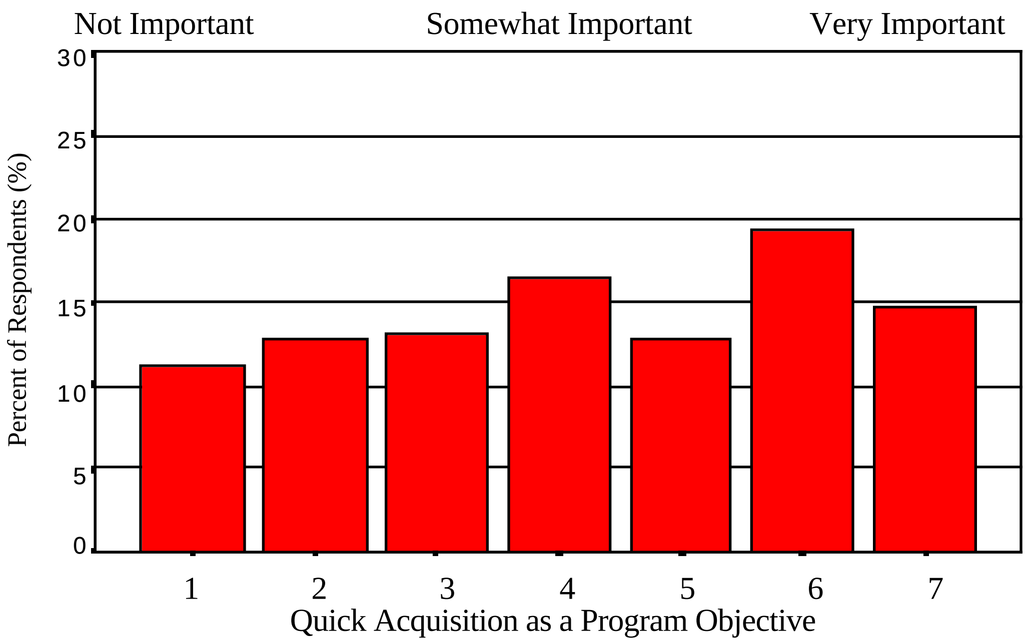


Figure 8-6: Short Acquisition Cycle as a Program Objective, Reported by Project Managers and Program Element Monitors (Program Office and Contractor Surveys; Number of Projects = 206).

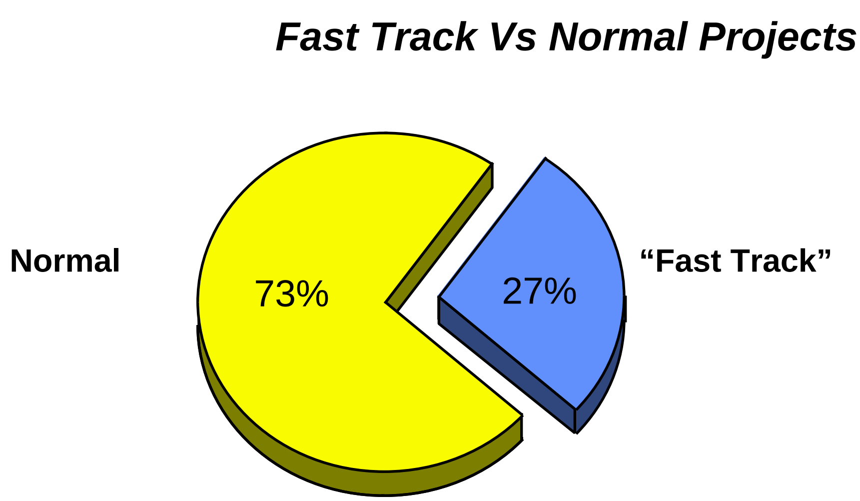


Figure 8-7: Projects Reportedly on a Fast Track--Having an Officially Accelerated Acquisition Cycle (Program Office, Pentagon, and Contractor Surveys; Number of Projects = 317).

C. Determining a Project's Starting Date

The Program Office and Pentagon surveys asked a series of questions to determine which organizations are responsible for initiating projects, and what factors are considered in establishing a project's starting date.

The Program Office survey asked program managers to identify the organizations that initially promoted the project concept or provided funding. They reported that the services' user commands (48 percent) or service headquarters (21 percent) initiated the majority of current projects. A smaller percentage of projects were started by development and logistics centers (9 percent), other services (4 percent), contractors (4 percent), elected or appointed government officials (3 percent), the Defense Advanced Research Projects Agency (>1 percent), or other entities (10 percent). The individual services, through the users, service headquarters, and development and logistics centers, initiated at least 78 percent of the projects surveyed.

To understand the process used to select the projects, the Pentagon survey asked if a project was initiated through the formal modernization planning process or through specific leadership direction. As described in Chapter 3, the modernization planning process is intended to identify and prioritize new systems and modifications needed to meet operational requirements in each mission area. Survey results indicated that 58 percent of the projects were initiated through the modernization planning process, while 42 percent of all projects were initiated outside that process through senior leadership direction.

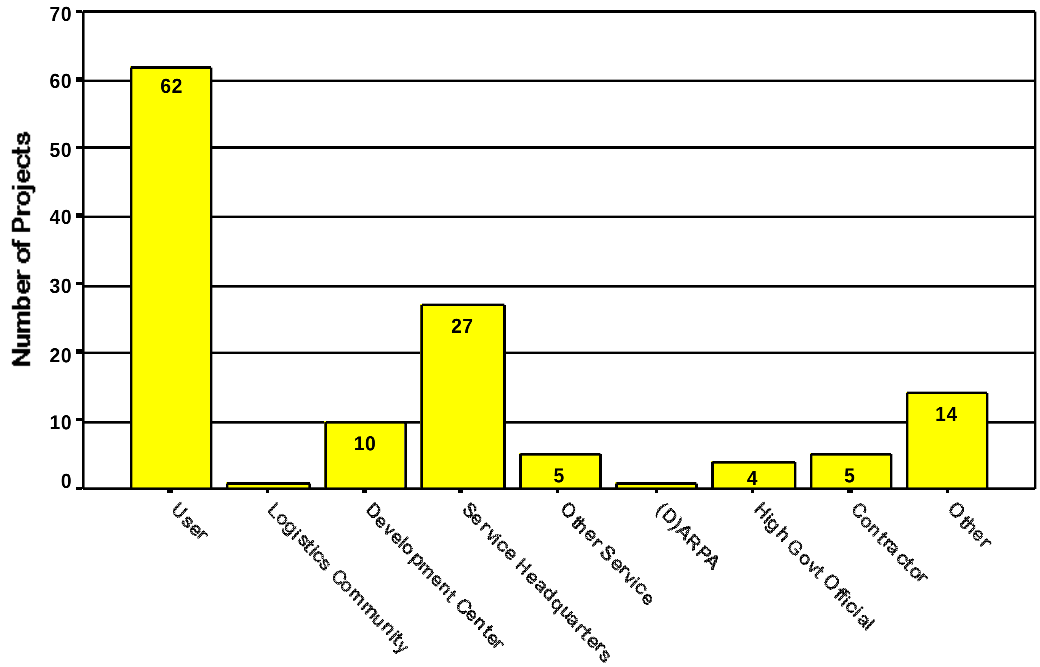


Figure 8-8: Number of Projects Initiated by Various Organizations (Program Office Survey; Number of Projects = 129).

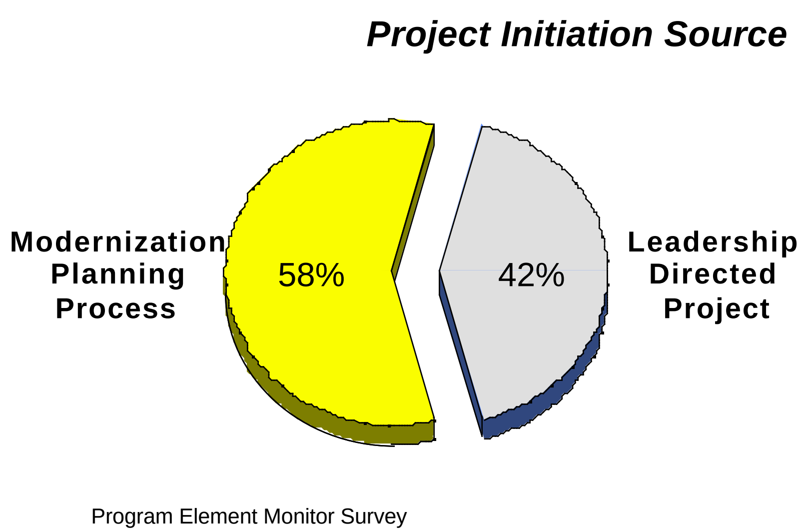


Figure 8-9: Percentage of Projects Started Through the Modernization Planning Process and Senior Leadership Direction (Pentagon Survey; Number of Projects = 60).

The Pentagon survey asked respondents to rate factors thought to influence starting dates for their projects on a scale of 1 to 7, from "no impact" to "defining impact." Although caution must be taken when using average data, they do shed light on the influence of various factors. Besides the average responses, the factors were also grouped statistically using the Wilcoxon ranked sign-test, a paired-sample non-parametric test.

The results show that the primary influences in setting a project's starting date are the user's desires and the desires of the service leadership. These factors were rated significantly higher than any other factor. They were followed by funding-related aspects, including the expected availability of development funding, the expected availability of production funding, and the results of the service planning process, which allocates resources.

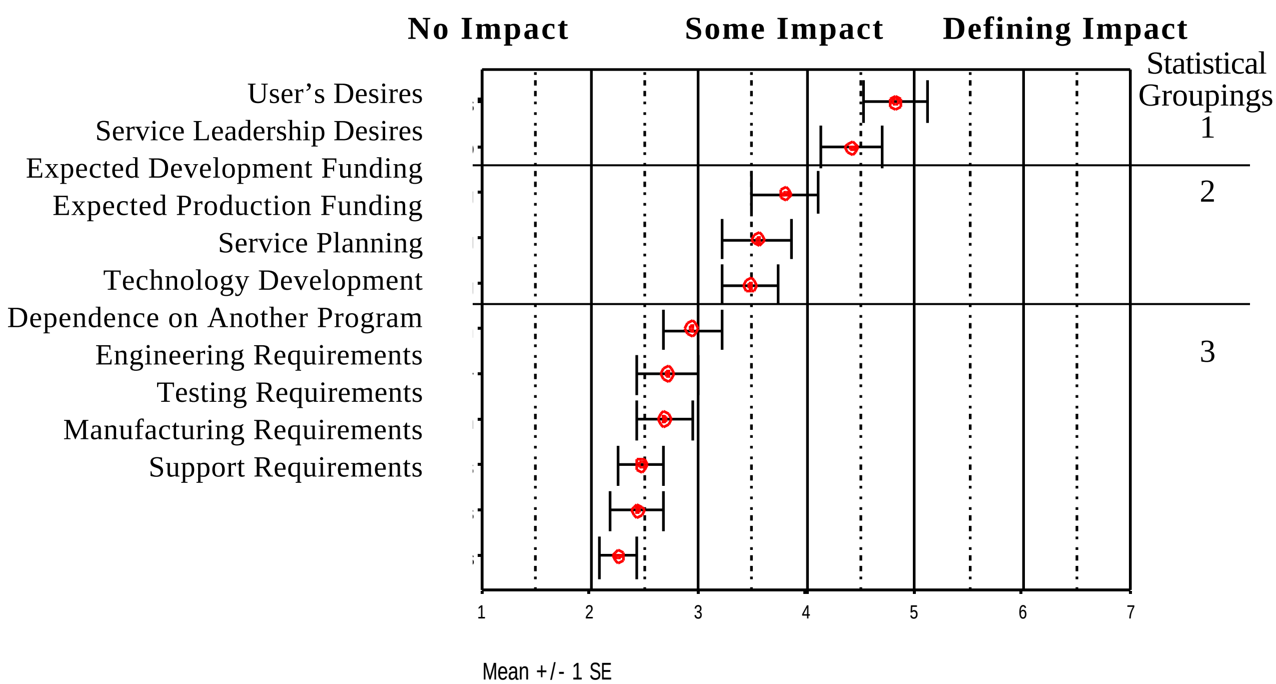


Figure 8-10: Impact of Various Factors in Determining a Project's Starting Date (Pentagon Survey Number of Projects = 52; Error Bars = +/-1 SE[97]).

[97] Note: The error bars shown are determined using plus or minus one standard error of the mean and the statistical groups are determined using the Wilcoxon non-parametric statistical test as described in Chapter 7.

The remaining factors form a third statistical group that includes circumstances typically associated with actual requirements: technology development, engineering development, and development of the manufacturing process. This group also includes testing requirements, support requirements, and dependence on other programs. The Program Element Monitors and Pentagon action officers report that these factors have a significantly smaller impact. The user's desires were reported to have a larger impact 6 times more often than technology development (30 projects to 5 projects). (Technology development was the highest-rated development-related factor.) Fifteen projects reported the two factors as tied. Table 8-2 shows the number of projects for which the user's desires were rated as having a larger impact than other factors.

Other Factor	Number of Projects Rating User's Desires Higher	Number of Projects Rating Other Factor Higher	Number of Projects Rating Them Equal
Service Leadership Desires	20	10	21
Expected Development Funding	24	10	16
Expected Production Funding	25	5	18
Service Planning	30	8	11
Technology Development	30	5	15
Dependence on Another Program	29	6	15
Engineering Requirements	31	4	15
Testing Requirements	35	1	14
Manufacturing Requirements	31	6	16
Support Requirements	36	2	12

Table 8-2: Reported Influence of User's Desires vs. Other Factors in Determining a Project's Starting Date (Pentagon Survey; Number of Projects = 51).

Once a project is started, planning activities used to manage the development begin. One aspect of planning is development of the project's initial schedule. The parties that develop the project's initial schedule, and the factors that influence its length, will be addressed next.

D. The Parties Involved in Developing a Project's Initial Schedule

The Program Office and Pentagon surveys asked respondents to indicate the involvement and influence of various organizations in developing their project's initial schedule. This was done using a 7-point scale ranging from "not involved" to "extensively involved." The responses show that in a majority of projects, Program Offices are significantly more involved in developing the initial schedule than any other group. The users are the second most involved, while potential contractors were reported third. Program Offices were reported to be more involved in developing the initial schedule in 5 times as many projects as the next-highest group, the users. (The figures were 70 versus 14 projects, with 52 reporting the two groups as equally involved.) Figure 8-12 and Table 8-3 compare Program Office involvement and the involvement of other organizations.

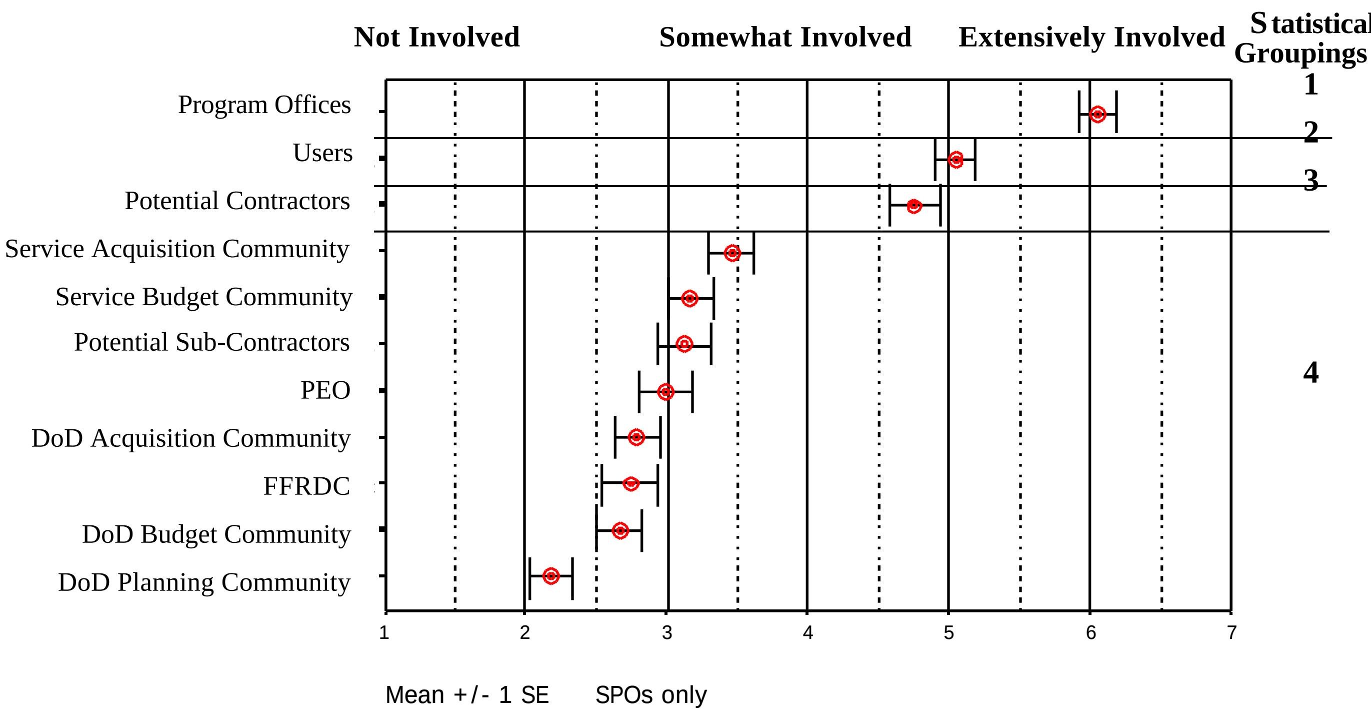


Figure 8-11: Organizational Involvement in Setting the Initial Project Schedule (Program Office Survey; Number of Projects = 137).

The relative involvement of the Program Offices in establishing the initial schedule vs. the involvement of other organizations **Other organizations**	Number of Projects Rating Program Office Involvement Higher	Number of Projects Rating the Involvement of Other Organizations Higher	Number of Projects Rating Them Equal
Users	70	14	52
Potential Contractors	76	14	45
Service Acquisition Community	105	9	20
Service Budget Community	109	7	18
Potential Sub-Contractors	105	9	15
PEO	110	6	16
DoD Acquisition Community	113	8	12
FFRDC	103	8	20
DoD Budget Community	114	8	10
DoD Planning Community	118	6	7
Center Headquarters	111	3	17

Table 8-3: Involvement of the Program Office vs. Other Organizations in Establishing a Project's Initial Schedule (Program Office Survey; N=137).

Involvement in the process to develop a project's initial schedule does not necessarily imply influence. Pentagon survey respondents were asked to rank the influence of various groups on their project's initial schedule on a 7-point scale, from "not involved" to "sole influence." They reported that the Program Office and the users had the most influence, with those groups rating significantly higher than all other organizations. The next group of organizations reportedly influencing a project's initial schedule are the service acquisition community and the service leadership. (This is more influence than would have been expected from the results of the Program Office survey.) The influence of other organizations, including potential contractors, the services, and DoD planning and budgeting communities, was rated significantly lower than that of the first four groups. Figure 8-14 shows the reported influence of the various organizations across all projects included in the Pentagon survey. Again, the Wilcoxon ranked-sign method was used to group factors statistically. Table 8-4 compares the reported influence of the Program Office with that of other organizations.

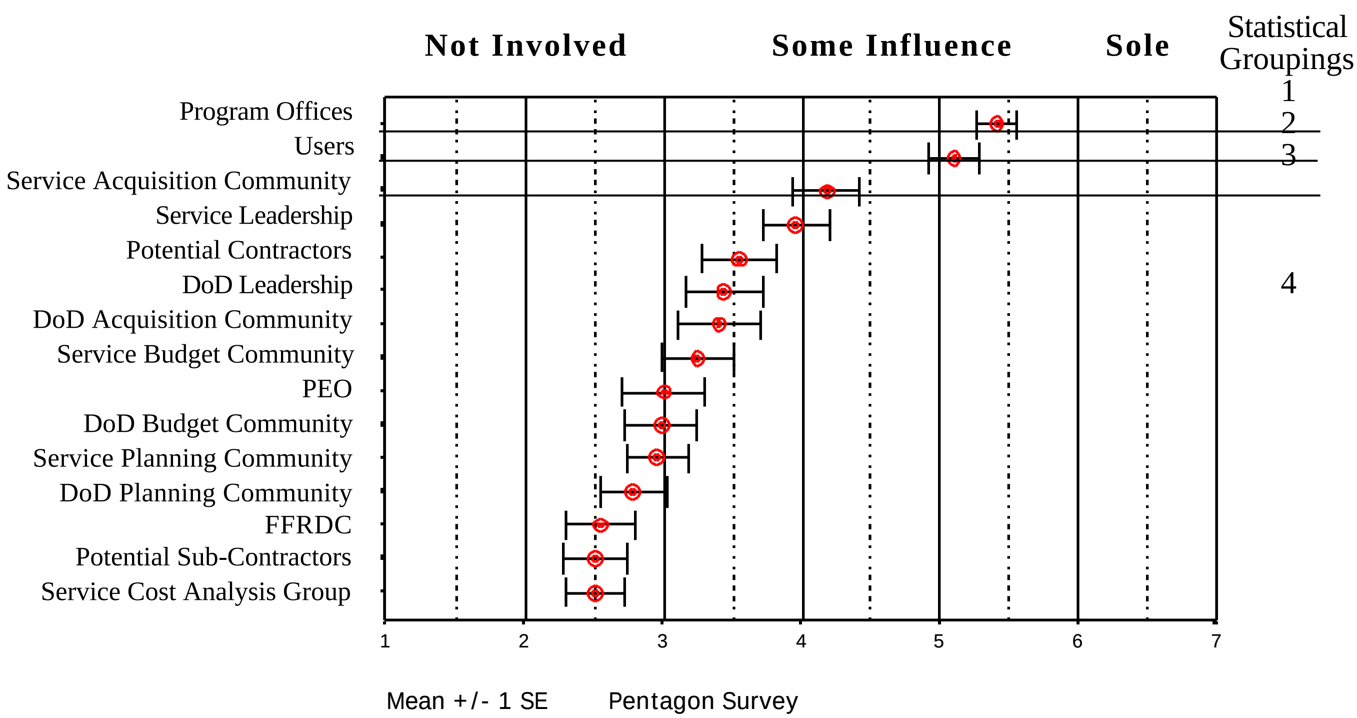


Figure 8-12: Organizational Influence in Setting the Initial Project Schedule, as Reported by Pentagon Respondents (Number of Projects = 52).

The relative influence of	Number of	Number of	Number

Program Offices vs. other organizations in establishing a project's initial schedule **Other organizations**	**Projects Rating Program Office Influence Higher**	**Projects Rating Other Organizations' Influence Higher**	**of Projects Rating Them Equal**
Users	**17**	**14**	**21**
Service Acquisition Community	**26**	**5**	**21**
Service Leadership Community	**29**	**6**	**17**
Potential Contractors	**34**	**4**	**12**
DoD Leadership	**35**	**7**	**10**
DoD Acquisition Community	**35**	**3**	**13**

Table 8-45: Reported Influence of Program Offices versus Other Organizations in Determining the Initial Project Schedule (Pentagon Survey; Number of Projects = 52).

The Program Offices reported significant involvement by contractors in the initial project schedule, but Pentagon respondents indicated that defense contractors had significantly less influence than the service acquisition community and the service leadership. In the Pentagon survey, 48 percent of respondents indicated that the service acquisition community had more influence than defense contractors, while 24 percent reported that the defense contractors had more influence than the service acquisition community. Twenty-eight percent reported the influence of the two organizations as the same. It is unclear whether these results reflect differences in organizational perspectives.

As would be expected, the Office of the Secretary of Defense was more involved in the largest development programs than in smaller programs. However, even for large programs, the involvement and influence of OSD organizations was still much below those of service users and Program Offices.

The analysis indicates that the primary organizations involved in developing project schedules are the Program Offices and the users. Potential contractors are often involved but have less influence. The planning, budget, and cost analysis groups, federally funded research and development centers, and potential subcontractors do not play a significant role, nor does DoD for most projects.

E. The Factors Determining the Length of a Project's Initial Schedule

To determine the influences on length of a project's initial schedule, the Program Office and the Pentagon Surveys asked respondents to rate a number of factors identified during preliminary interviews and literature research. The respondents rated these factors on a scale of 1 to 7, ranging from "no impact" to "defining impact." The average responses provide an understanding of the relative importance of different factors across all the projects. The Wilcoxon ranked-sign test was also used to identify groups of factors that can be separated from the others on a statistical basis.

The factors reportedly having the largest impact are the user's desires and the availability of development funding. These factors were rated statistically higher than all other factors. They were followed by the availability of expected production funding. The factors typically associated with development-related aspects—engineering requirements, technological development, and development of the manufacturing process—rated significantly lower, ranking fourth, seventh, and tenth among 11 factors, respectively.

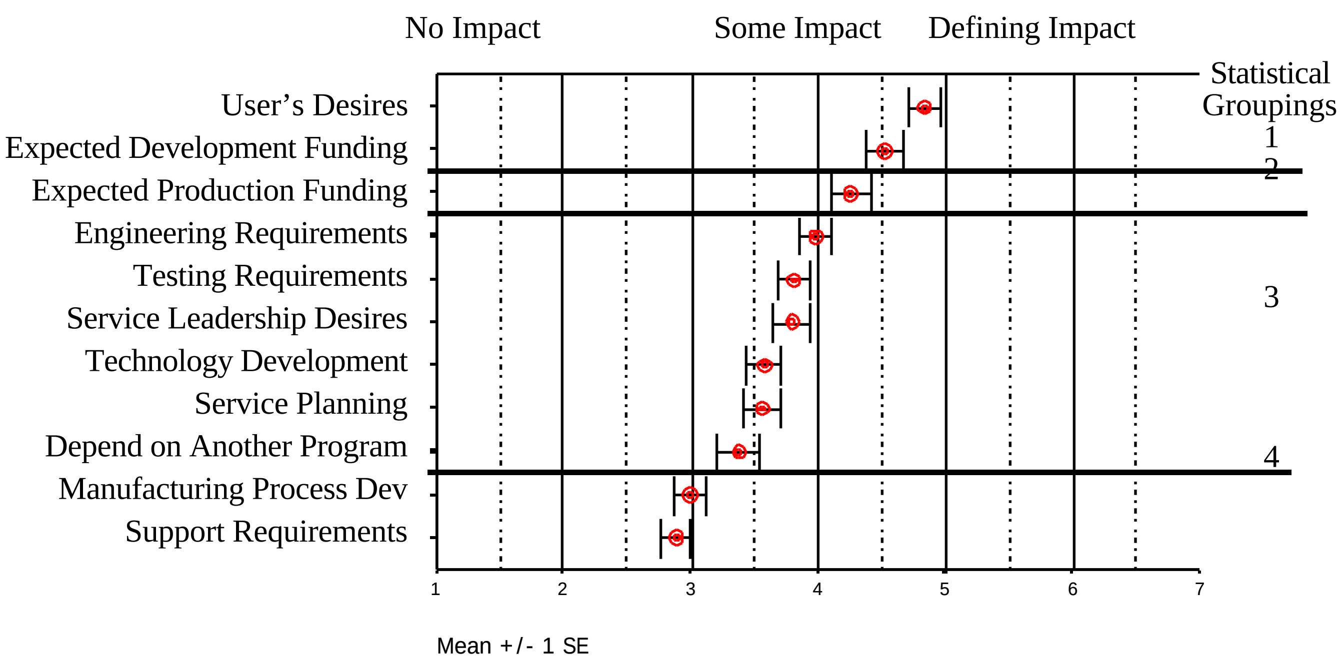


Figure 8-13: Factors Affecting the Length of a Project's Initial Schedule (Pentagon and Program Office Surveys; Number of Projects = 178).

Both the Program Office and the Pentagon surveys rated users' desires and the availability of development and production funding as having the largest impact. Notable differences between the two surveys did appear, such as in the ranking of testing requirements and service planning. But both surveys reported technology development and the manufacturing process as having a low reported impact on the length of the development schedule.

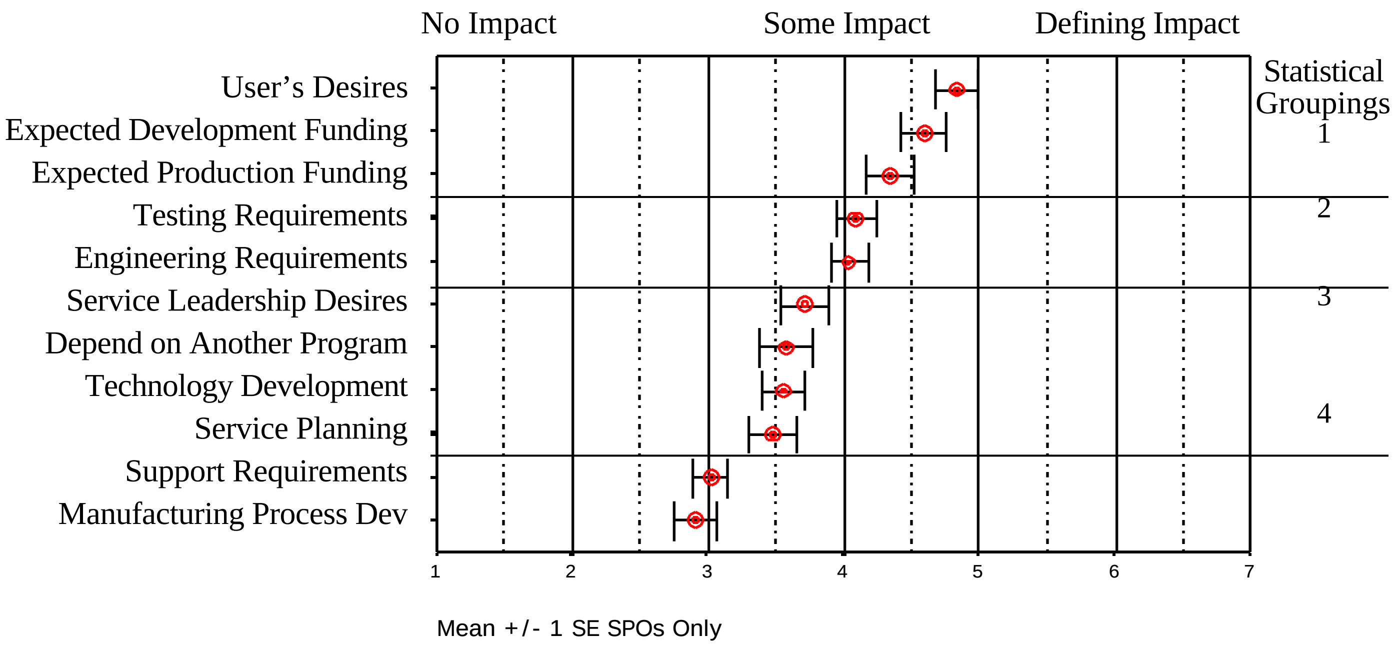


Figure 8-14: Average Rating for Factors Used to Determine the Length of Initial Project Schedule (Program Office Survey; Number of Projects = 126).

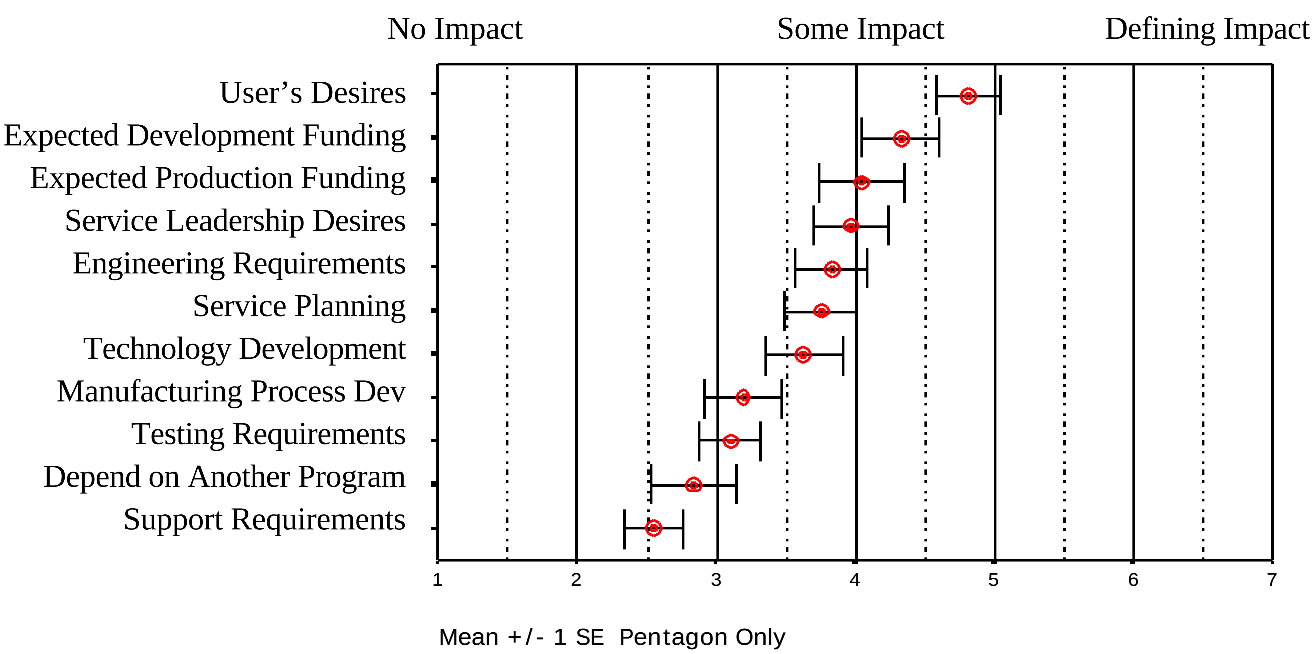


Figure 8-15: Average Rating for Factors Used to Determine the Length of Initial Project Schedule (Pentagon Survey; Number of Projects = 52).

Averaging the data may mask important aspects of the information. Analyzing the responses on a factor-by-factor and project-by-project basis makes clear that user's desires, expected development funding, and expected production funding have a larger impact on most projects than other factors. The tables on the next page show the project-by-project comparison of responses regarding the user's desires, expected development funding, and expected production funding versus other factors.

The user's desired date and expected development funding are rated more important on approximately the same number of projects. For example, 69 projects rated the user's desires as more important than expected development funding, while 64 projects rated expected development funding higher than the user's desires. Forty-four projects rated them equal. These responses cannot be statistically separated. In contrast, the user's desires were rated as having more influence on twice as many projects (88 to 42) as engineering requirements.

When viewed across all projects, expected development funding has a larger impact on the length of the initial project schedule than any development-related aspects, including technology development, engineering requirements, and development of the manufacturing process. For example, expected development funding had a larger impact than engineering requirements in 88 projects, and a smaller impact than engineering requirements in 57 projects. Expected development funding had a larger impacts than technology development in 100 projects, and a smaller impact in 42 projects. Expected development funding had a larger impact than manufacturing process development in 118 projects, while ranking lower in 26 projects. These differences are significant based on the non-parametric paired-sample sign test at the 0.01 percent, 1 percent and 0.01 percent levels, respectively. Clearly the expected development funding plays a major role in the length of a project's initial schedule.

Factors Influencing the Length of the Project Schedule
User's Desires vs. Other Factors

The reported relative impact of the user's desired schedule vs. other factors on the length of a project's initial schedule **Other Factors**	Number of Projects Rating User's Desires Higher	Number of Projects Rating Other Factors Higher	Number of Projects Rating Them Equal
Expected Development Funding	69	64	52
Expected Production Funding	78	53	41
Engineering Requirements	88	42	47
Testing Requirements	98	42	38
Service Leadership Desires	87	20	69
Technology Development	105	38	34
Service Planning	96	24	53
Dependence on Another Program	109	39	25
Manufacturing Process Development	118	26	31
Support Requirements	129	20	26

Expected Development Funding vs. Other Factors

The reported relative impact of expected development funding vs. other factors on the length of the initial schedule **Other Factors**	Number of Projects Rating Expected Dev Funding Higher	Number of Projects Rating Other Factors Higher	Number of Projects Rating Them Equal
User's Desires	64	69	52
Expected Production Funding	41	24	108
Engineering Requirements	88	57	33
Testing Requirements	101	51	27
Service Leadership Desires	91	45	41
Technology Development	100	42	35
Service Planning	104	38	32
Dependence on Another Program	96	44	33
Manufacturing Process Development	118	26	32
Support Requirements	121	29	25

Expected Production Funding vs. Other Factors

The reported relative impact of expected production funding vs. other factors on the length of a project's initial schedule **Other Factors**	Number of Projects Rating Expected Prod Funding Higher	Number of Projects Rating Other Factors Higher	Number of Projects Rating Them Equal
User's Desires	53	78	41
Expected Development Funding	24	41	108
Engineering Requirements	78	60	35
Testing Requirements	83	55	36
Service Leadership Desires	79	50	43
Technology Development	88	47	37
Service Planning	85	38	46
Dependence on Another Program	85	47	36
Manufacturing Process Development	99	20	47
Support Requirements	103	27	40

Tables 8-5, 8-6, and 8-7: Number of Projects Reporting the Impact of the User's Desires, Expected Development Funding, and Expected Production Funding as

Larger, Smaller, or Equal to Other Factors in Determining Length of a Project's Initial Schedule

These results appear to contradict earlier results indicating that users wanted 80 percent of projects as soon as possible. This contradiction was discussed during presentation of the data at the Aeronautical Systems Center, the Electronic Systems Center, the Pentagon, and MIT. The strong consensus of participants at each location was that users' desires were determined primarily by expected development and production funding, not their actual operational needs. This is also consistent with results from other survey questions.

In a related question, the Pentagon survey asked respondents to choose between two factors limiting their project's schedule: funding, and technology and engineering. Seventy-seven percent indicated that funding was the limiting factor, supporting the earlier conclusions.

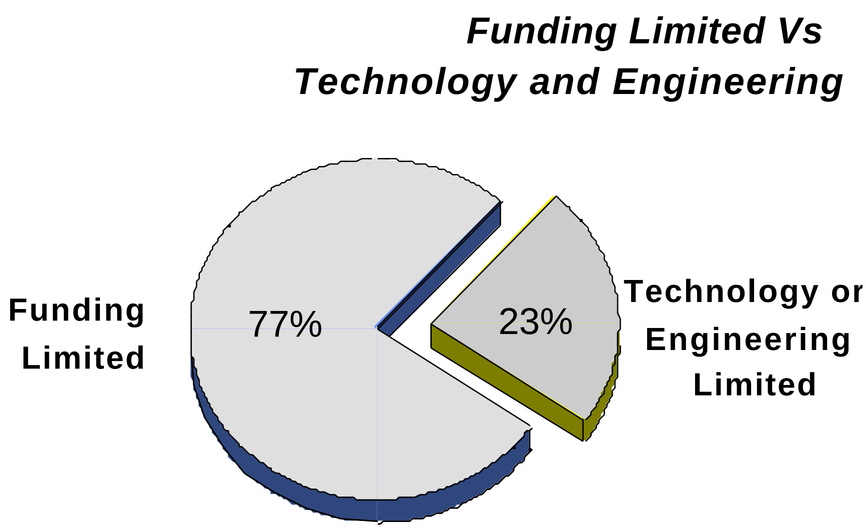


Figure 8-16: Percent of Respondents Reporting the Limiting Factor for Their Project's Schedule as Funding or Technology and Engineering (Pentagon Survey; Number of Projects = 61).

The finding that expected funding availability has a larger impact than development-related factors is consistent across all types, sizes, and technological levels of projects. This consistency indicates that the finding is systemic across the entire range of projects and the entire development process, and cannot be dismissed as resulting from specific circumstances. The following graphs show the average reported impact of each factor on different subgroups of projects.

The Impact of Expected Development Funding vs. Engineering Requirements on Length of a Project’s Initial Schedule

	# Projects Rating Expected Development Funding More Important	# Projects Rating Engineering Requirements More Important	# Rating Them Equally Important	Total Number
All Projects	88	57	33	178

By System Type	# Projects Rating Expected Development Funding More Important	# Projects Rating Engineering Requirements More Important	#Rating Them Equally Important	Total Number
Aircraft	35	24	14	73
Spacecraft	5	3	0	8
Electronics	10	5	5	20
Missiles and Munitions	15	6	3	24
Software	13	10	3	26
Other	9	8	6	23

By Project Size	# Projects Rating Expected Development Funding More Important	# Projects Rating Engineering Requirements More Important	# Rating Them Equally Important	Total Number
ACAT I Programs	32	18	9	59
ACAT II Programs	14	10	6	30
ACAT III Programs	42	28	17	86

By Technological Advance	# Projects Rating Expected Development Funding More Important	# Projects Rating Engineering Requirements More Important	#Rating Them Equally Important	Total Number
Revolutionary Product	10	8	1	19
New Generation Product	30	22	10	62
Incremental Improvement	46	27	22	95

By Organization	# Projects Rating Expected Development Funding More Important	# Projects Rating Engineering Requirements More Important	#Rating Them Equally Important	Total Number
Pentagon	25	16	11	52
Program Office	63	41	22	126

Table 8-8: Number of Projects Reporting the Impact of Expected Development Funding as Larger, Smaller, or Equal to Engineering Requirements in Determining Length of Initial Schedule (Pentagon and Program Office Surveys: Number of Projects = 178).

Impact of Expected Development Funding vs. Technology Development on Length of Initial Project Schedule

	Expected Development Funding Rated More Important	Technology Development Rated More Important	Rated Equally Important	Total Number
All Projects	100	42	35	177

By System Type	Expected Development Funding Rated More Important	Technology Development Rated More Important	Rated Equally Important	Total Number
Aircraft	43	17	13	73
Spacecraft	5	3	0	8
Electronics	10	5	5	20
Missiles and Munitions	14	4	6	24
Software	15	6	5	26
Other	11	7	5	23

By Project Size	Expected Development Funding Rated More Important	Technology Development Rated More Important	Rated Equally Important	Total Number
ACAT I Programs	36	12	11	59
ACAT II Programs	16	6	8	30
ACAT III Programs	48	23	15	86

By Technological Advance	Expected Development Funding Rated More Important	Technology Development Rated More Important	Rated Equally Important	Total Number
Revolutionary Product	9	8	2	19
New Generation Product	35	17	10	62
Incremental Improvement	55	17	23	95

By Organization	Expected Development Funding Rated More Important	Technology Development Rated More Important	Rated Equally Important	Total Number
Pentagon	26	16	9	52
Program Office	74	26	26	126

Table 8-9: Number of Projects Reporting the Impact of Expected Development Funding as Larger, Smaller, or Equal to Technology Development in Determining Length of Initial Schedule (Pentagon and Program Office Surveys; Number of Projects = 178).

Impact of Expected Development Funding vs. Manufacturing Process on Length of Initial Project Schedule

	Expected Development Funding Rated More Important	Manufacturing Process Development Rated More Important	Rated Equally Important	Total Number
All Projects	118	26	32	176

By System Type	Expected Development Funding Rated More Important	Manufacturing Process Development Rated More Important	Rated Equally Important	Total Number
Aircraft	43	13	16	72
Spacecraft	5	1	2	8
Electronics	13	2	6	21
Missiles and Munitions	18	4	2	24
Software	20	3	2	25
Other	18	2	3	23

By Project Size	Expected Development Funding Rated More Important	Manufacturing Process Development Rated More Important	Rated Equally Important	Total Number
ACAT I Programs	38	9	12	59
ACAT II Programs	20	3	6	29
ACAT III Programs	60	13	13	86

By Technological Advance	Expected Development Funding Rated More Important	Manufacturing Process Development Rated More Important	Rated Equally Important	Total Number
Revolutionary Product	12	3	4	19
New Generation Product	41	11	10	62
Incremental Improvement	64	12	17	93

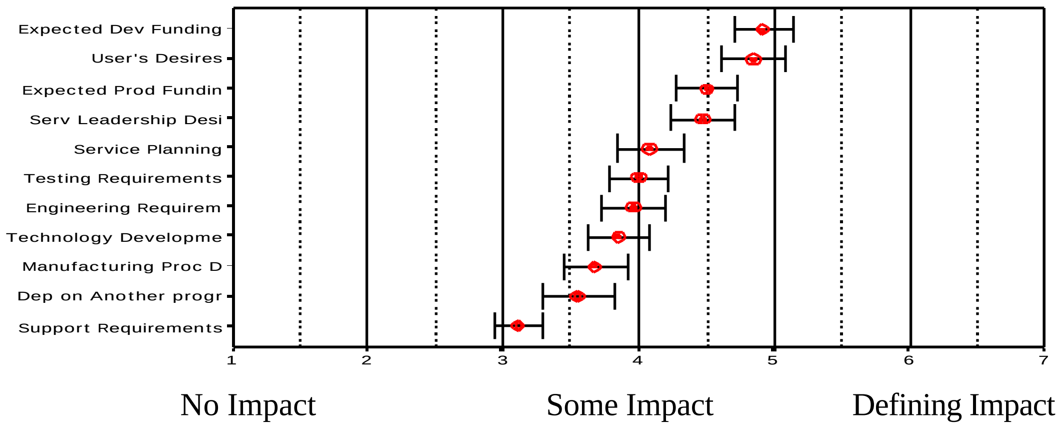
By Organization	Expected Development Funding Rated More Important	Manufacturing Process Development Rated More Important	Rated Equally Important	Total Number
Pentagon	29	12	11	52
Program Office	89	12	21	124

Table 8-11: Number of Projects Reporting the Impact of Expected Development Funding as Larger, Smaller, or Equal to Manufacturing Process in Determining

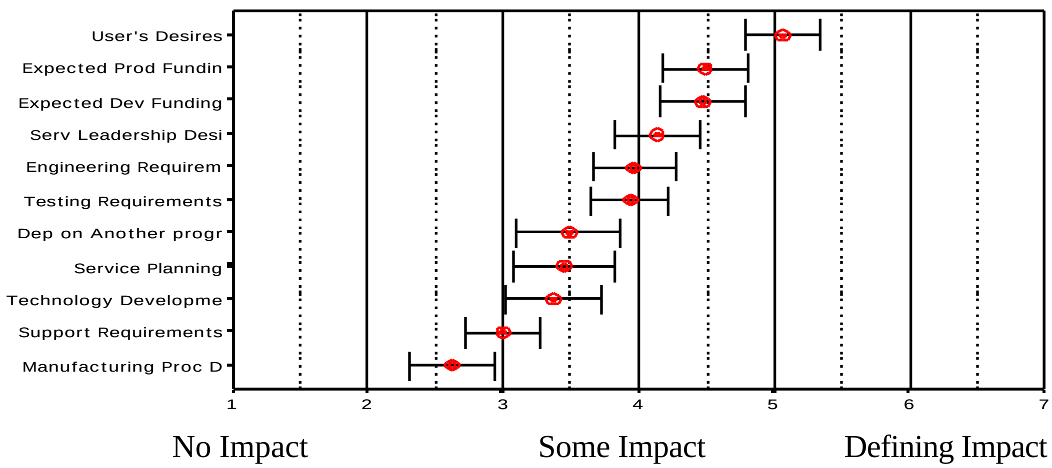
Length of Initial Schedule (Pentagon and Program Office Surveys; Number of Projects = 178).

Factors Affecting the Length of the Initial Project Schedule

Acquisition Category I Projects



Acquisition Category II Projects



Acquisition Category III Projects

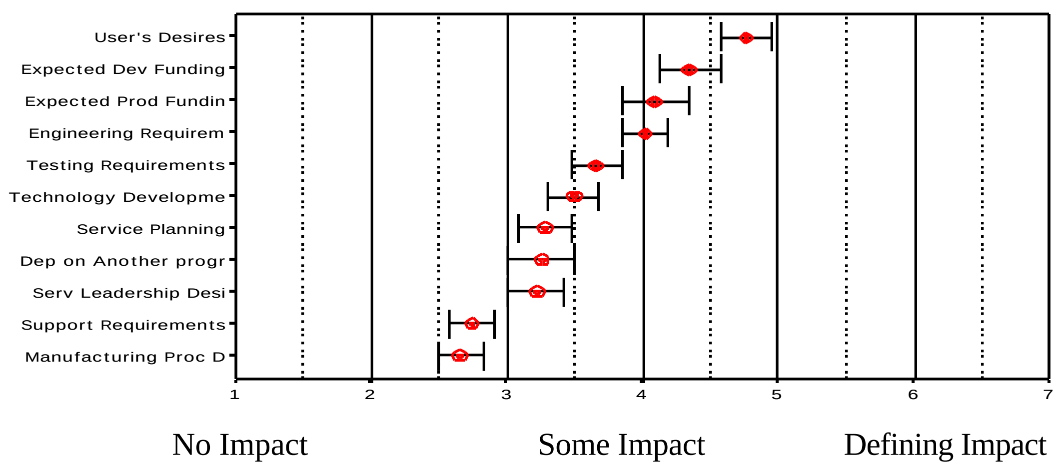


Figure 8-17: Factors Affecting Length of Initial Project Schedule, by Acquisition Category and Program Size (Program Office and Pentagon Surveys; Number of Projects: ACAT I = 60, ACAT II = 31, ACAT III = 88).

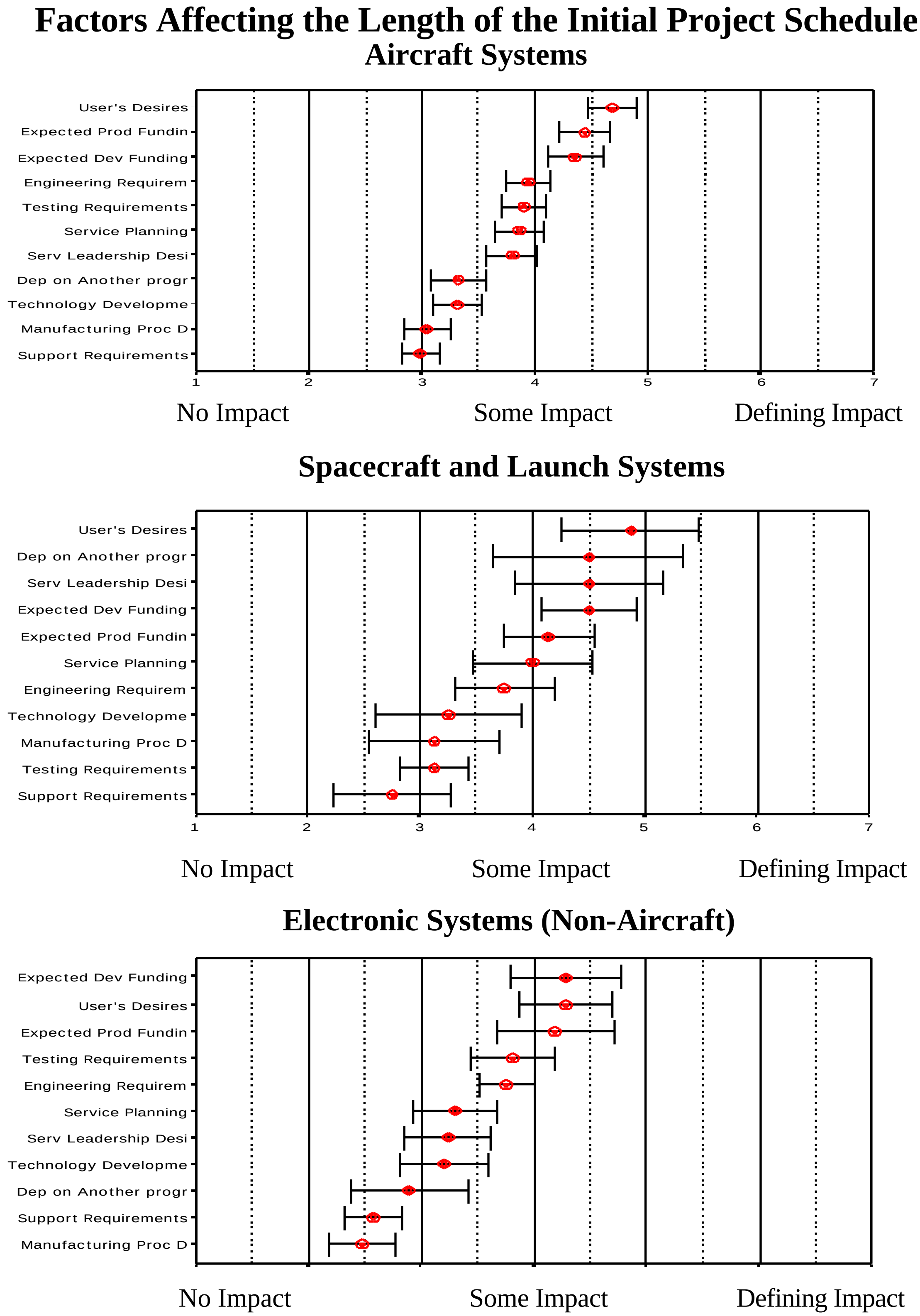


Figure 8-18: Factors Affecting Length of a Project's Initial Schedule by Type of System (Program Office and Pentagon Surveys; Number of Projects: Aircraft = 74, Space Systems = 8, Electronic Systems = 21).

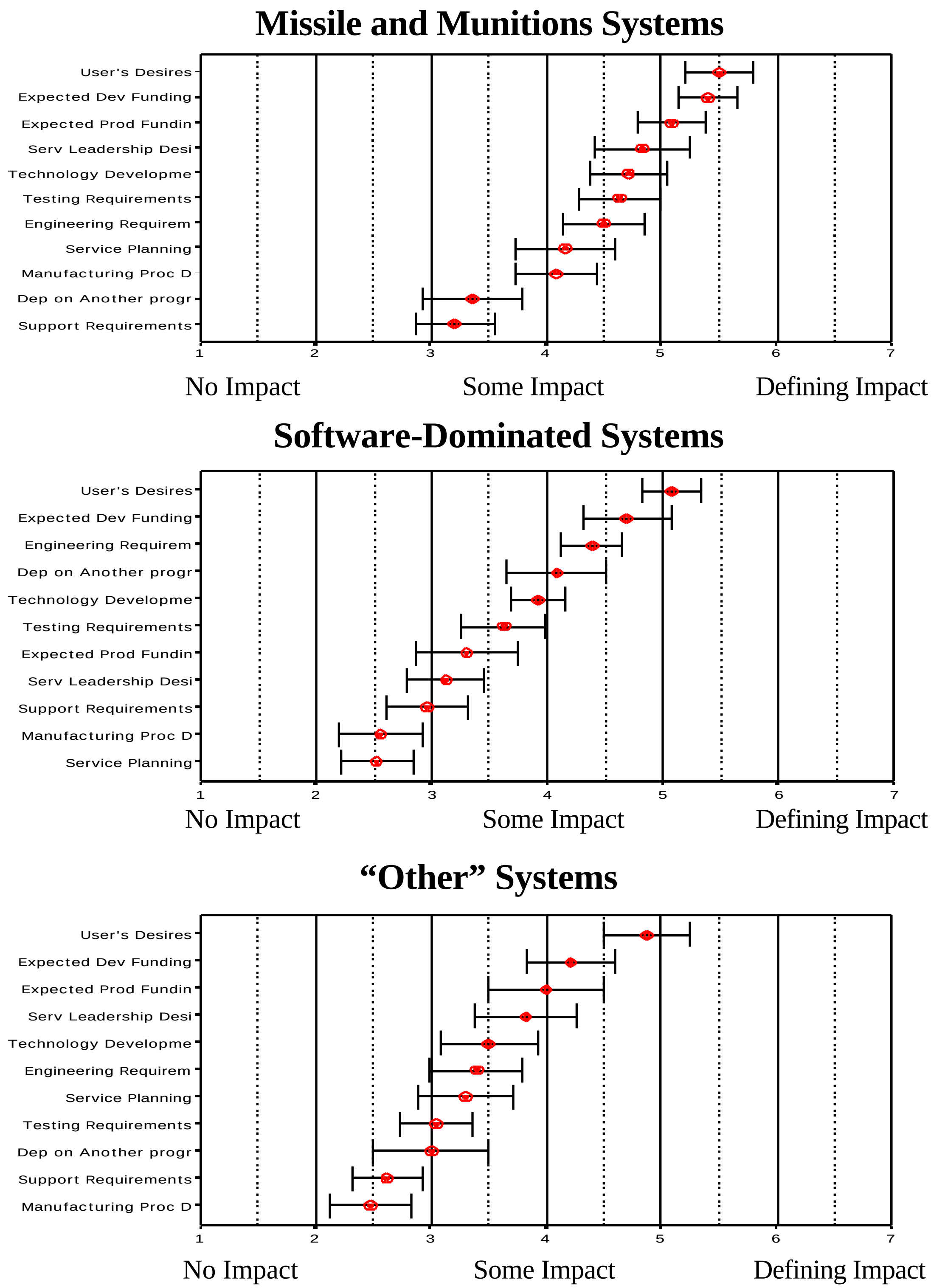


Figure8-19: Factors Affecting Length of a Project's Initial Schedule by Type of System (Program Office and Pentagon Surveys; Number of Projects: Missiles and Munitions = 24, Software-Dominated = 26, Other = 24).

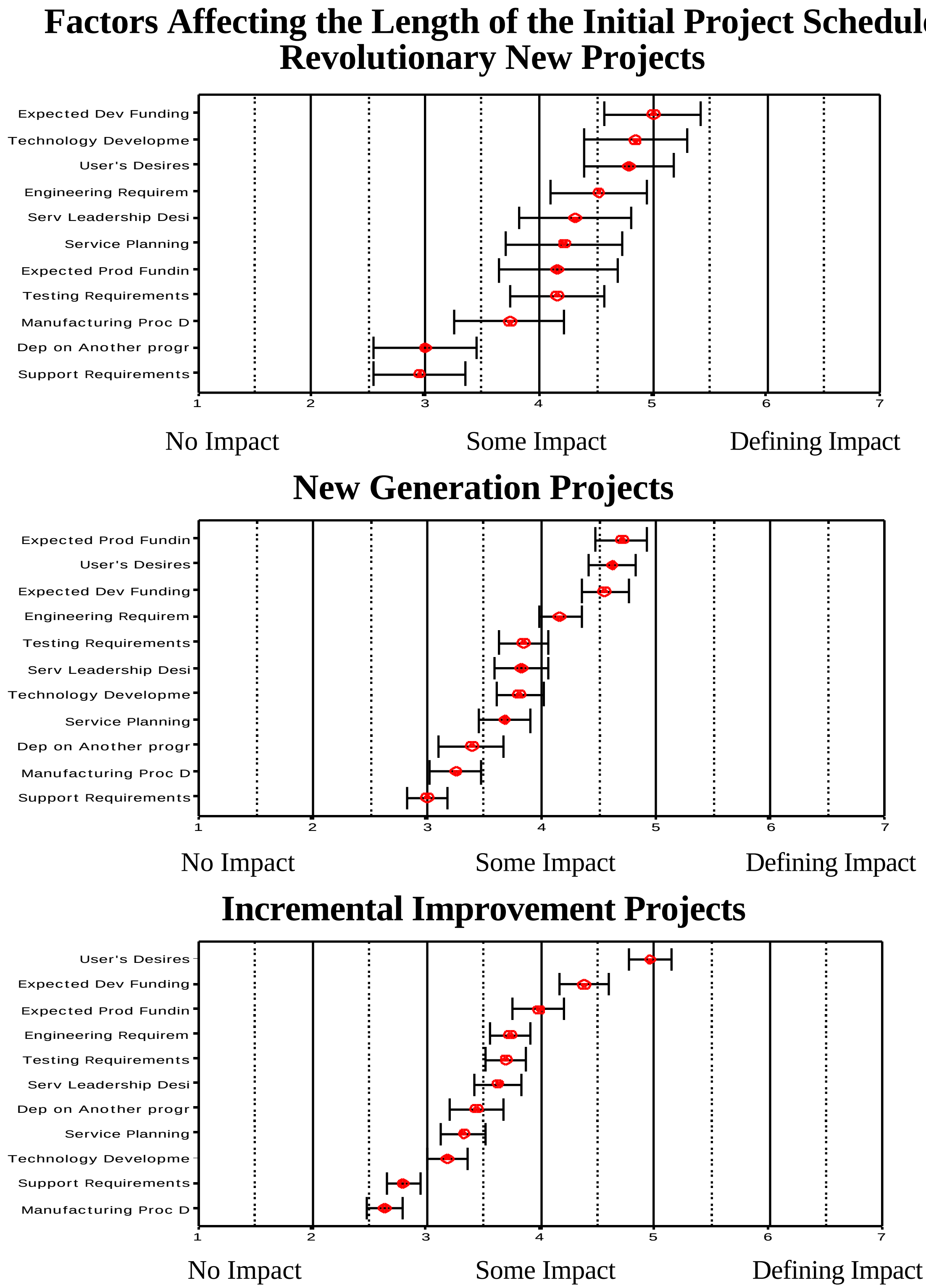


Figure 8-20: Factors Affecting Length of a Project's Initial Schedule by Technological Advance of the Product (Program Office and Pentagon Surveys; Number of Projects: Revolutionary = 19, New Generation = 63, Incremental = 96).

F. Factors Determining a Project's Initial Funding Profile

Because of the influence of expected development and production funding, the Pentagon survey asked respondents to rate the factors affecting a project's initial funding profile. The responses identified the Pentagon's planning, programming, and budgeting system (PPBS) as the primary factor--rated as having more impact nearly twice as often as the next highest-rated factor, --the funding profile proposed by the Program Office. All other factors rated consistently and considerably lower, as shown in Figure 8-23.

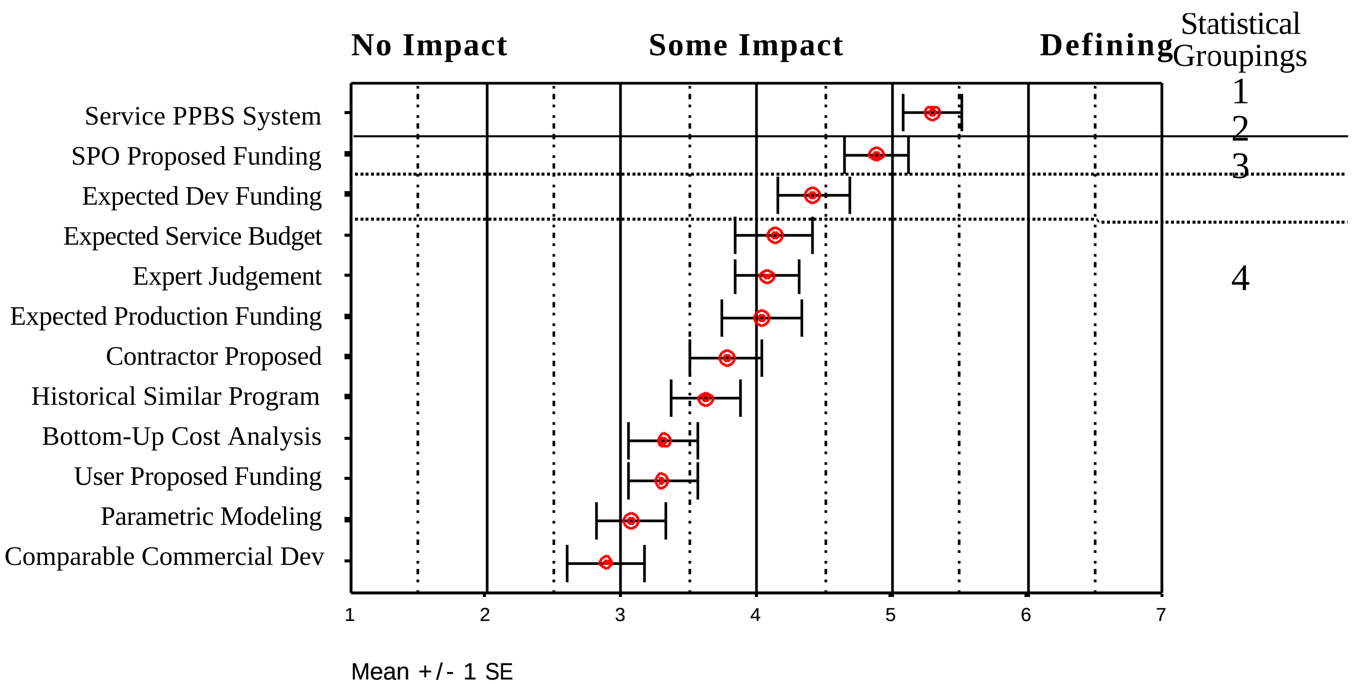


Figure 8-21: Average Responses to Factors Influencing a Project's Initial Funding Profile (Pentagon Survey; Number of Projects = 54).

Another observation is that information-based factors, such as contractor-proposed funding profiles, historically similar programs, bottom-up or task-based development of funding profiles, and commercially comparable programs, average near the bottom in impact on initial funding profile at the Pentagon level. It is possible that these factors are not explicitly considered at the Pentagon level, being more important in the Program Office funding profile. However, the PPBS appears to overshadow even the Program Office's proposed funding profile in its impact on initial funding profiles.

Table 8-11 shows the number of projects rating the PPBS process as having a larger or smaller impact than other factors on the initial funding profile. Pentagon responses rated the PPBS process as having over 8 times the impact of the user's proposed funding profile. The large disparity between the impact of the Pentagon PPBS process and the user's proposed funding profile indicates that funding-related decisions are made primarily at the Pentagon, not at the major commands.

Programming, Planning, and Budgeting System vs. Other Factors

The relative impact of the PPBS process vs. other factors in determining a project's initial funding profile Other Factors	**# Projects Rating the Impact of the PPBS Process Higher**	**# Projects Rating Other Factors Higher**	**# Rating Them Equal**
SPO Proposed Funding Profile	23	12	18
Expected Development Funding	23	4	26
Expected Service Budget	28	5	21
Expert Judgment	31	7	16
Expected Production Funding	26	5	21
Contractor Proposed Funding Profile	31	9	13
Historical Similar Program	35	5	14
Bottom-Up Cost Analysis	38	4	12
User Proposed Funding Profile	34	4	18
Parametric Modeling	39	5	10
Comparable Commercial Development	40	4	10

Table 8-11: Number of Projects Reporting the Impact of the Programming, Planning, and Budgeting System as Larger, Smaller, or Equal to Other Factors in Determining the Initial Funding Profile.

G. Schedule Information Used to Develop a Project's Initial Schedule

The Program Office survey asked respondents to indicate the source of the information they used to develop their initial project schedule. (The list of potential sources was based on interviews and related literature reviews.) The results indicate that the primary sources of information used by the Program Offices were expected development funding and "expert judgment" based on the participants' experience. Other factors related to development-related requirements, such as bottom-up schedule development, historically similar programs, and parametric modeling rated significantly lower, on average, and on a project-by-project and factor-by-factor comparison. Comparable commercial development efforts rated significantly lower than all other sources of information.

Follow-up discussions with program managers and other individuals revealed that the judgment appeared to rest on an individual's or group's previous experiences. Program managers most often described "expert judgment" as a best guess.

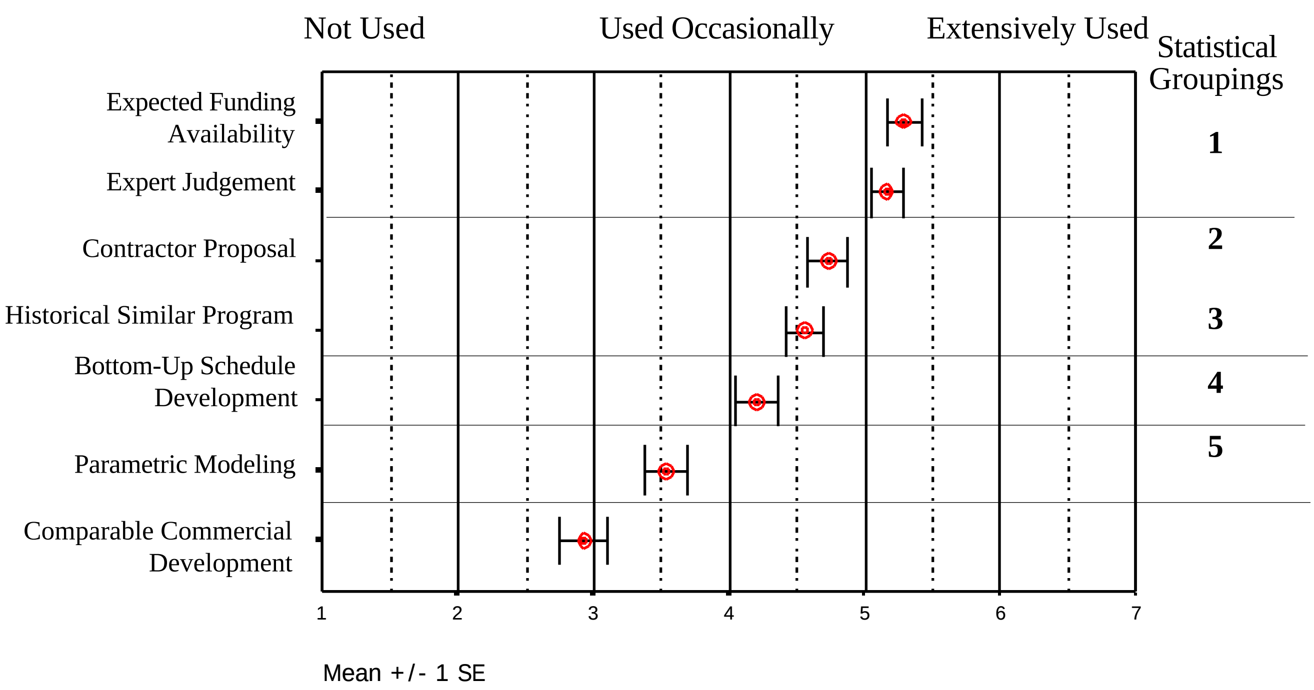


Figure 8-22: Average Responses Regarding Sources of Information Used to Determine a Project's Initial Schedule (Program Office Survey; Number of Projects = 130).

Relative use of expected development funding versus other sources of information in developing a project's initial schedule **Other Sources of Information**	**# Projects Rating Expected Development Funding Higher**	**# Projects Rating Other Tools or Sources of Information Higher**	**# Rating Them Equal**
Expert Judgment	51	41	36
Contractor Proposal	62	29	37
Historically Similar Project	64	30	34
Bottom-Up Schedule Development	67	19	42
Parametric Modeling or Estimation	85	15	24
Commercial Comparable Development	96	12	18

Table 8-12: Number of Projects Reporting Expected Funding as Greater Than, Lesser Than, or Equal to Other Information Sources in Determining a Project's Initial Schedule (Program Office Survey; Number of Projects = 130).

Few project managers reported using comparable commercial development efforts as a source of information in establishing initial development schedules. In fact, a majority reported that they do not consider such experiences in developing project schedules. These results contrast sharply with the number of respondents (49 percent) who attest to potential commercial markets for key technologies in their projects.

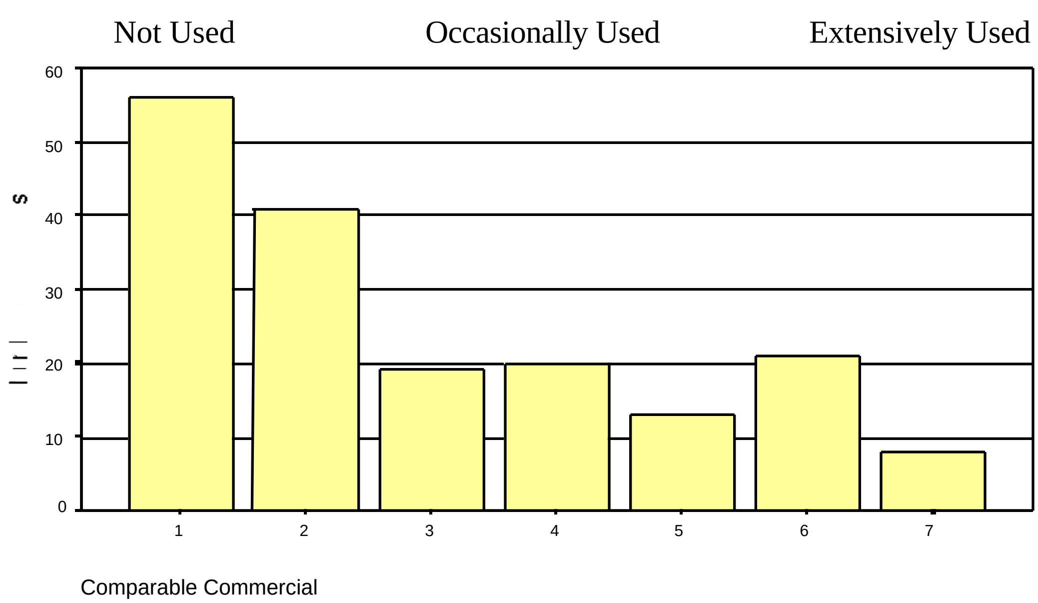


Figure 8-23: Reported Use of Comparable Commercial Development Efforts in Establishing the Initial Project Schedule (Program Office and Pentagon Surveys; Number of Projects = 178).

H. Use of Scheduling Tools to Develop a Project's Initial Schedule

The Program Office Survey asked project managers how extensively they used different scheduling tools to develop the initial schedule. Five potential scheduling tools had been identified through interviews and a literature search. These included the standard Gantt chart and milestone charts as well as the more sophisticated critical path management and PERT systems, and product center-based scheduling models. An "other" response was included in the event that a key tool was missed.

Project managers reported that the primary tool they used to develop the initial schedule was the relatively unsophisticated milestone chart (86 of 126 projects used such charts extensively). Gantt charts were the second most-used scheduling tool, employed in 58 projects. The more advanced tools were used significantly less frequently: 40 projects used critical path management extensively, and only 18 used PERT extensively. Just 8 projects indicated that they used other tools extensively—with Microsoft Project being most often cited. Only 4 projects used center-based schedule models extensively.

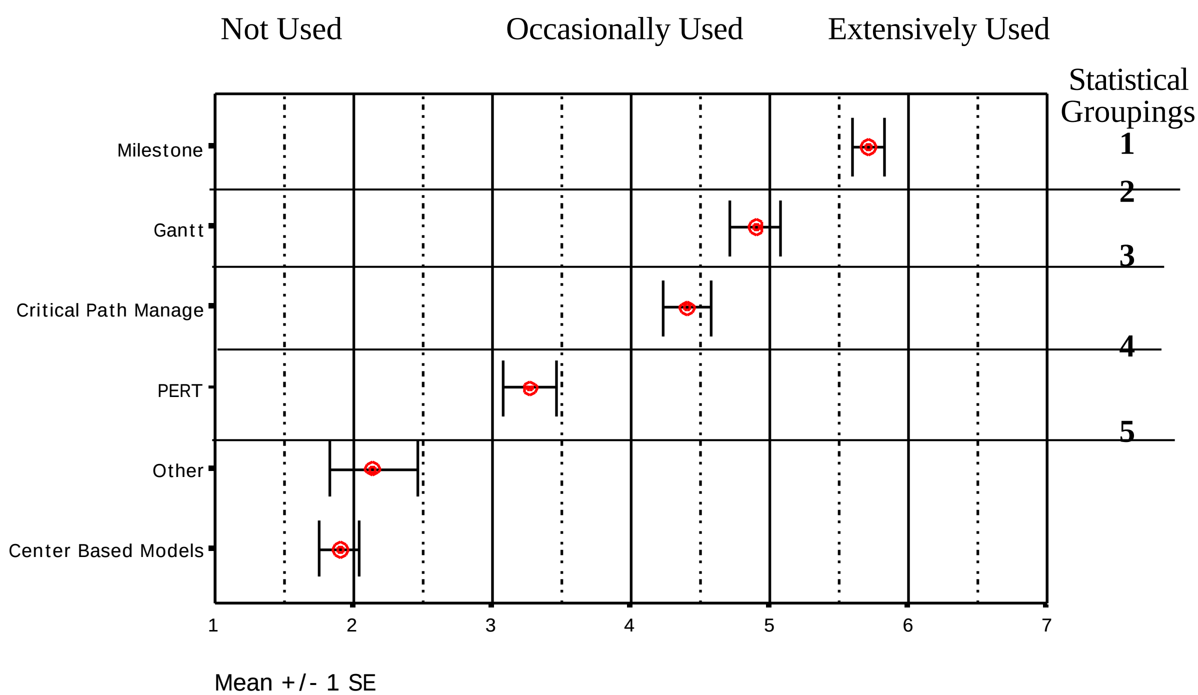


Figure 8-24: Schedule Tools Used by Program Offices to Develop a Project's Initial Schedule (Program Office Survey; Number of Projects = 126).

Other Factors	# Projects Using Milestone Charts	# Projects Rating Other Tools Higher	# Rating Them Equal
Gantt	44	19	55
Critical Path Management	65	12	40
PERT	81	9	20
Other	38	3	8

Center-Based Model	96	1	10

Table 8-13: Projects Reporting Use of Milestone Charts More or Less Often Than Other Scheduling Tools in Developing the Initial Schedule (Program Office Survey; Number of Projects = 126).

Scheduling Tools	Not Used		Occasionally Used			Extensively Used	
Numerical rating	1	2	3	4	5	6	7
Milestone	3	1	3	15	18	47	39
Gantt	13	8	5	13	24	30	28
Critical Path Mgmt.	13	11	7	27	21	25	15
PERT	32	13	16	22	12	10	8
Other	37	1	1	1	1	2	6
Center-Based Model	68	15	5	9	6	3	1

Table 8-14: Distribution of Responses Regarding Use of Various Schedule Tools to Develop a Project's Initial Schedule (Program Office Survey; Number of Projects = 126).

Summary on Development of a Project's Initial Schedule

A project's initial schedule is not determined by technology, engineering, or manufacturing requirements but instead primarily by funding-related constraints. Respondents reported that users wanted 80 percent of current projects as soon as possible, and that 70 percent of projects are intended to remedy existing deficiencies. But despite this reported need and sense of high project priority, project managers reported short schedules as the lowest project priority.

The starting date for a project is most often determined by the user's or leadership's desires. Secondary items in determining when to start a project are funding availability and service planning. Product development-related aspects, including technology development, engineering requirements, and manufacturing processes, do not play a significant role in determining when to start a project.

Program Offices primarily control the process used to develop the length of a project's initial schedule, with users, the service acquisition community, and potential contractors exerting less influence. Funding-based constraints, including the user's desires as limited by funding, and expected development and production funding, are most important in establishing the length of a project's initial schedule. Product development requirements, including engineering requirements, technology development, and manufacturing processes, rank well below funding-related constraints. This finding is consistent across projects of all sizes, types, and levels of technical advance. Schedules for 80 percent of current projects are limited by funding and not by technical or engineering constraints.

The primary sources of information used to develop initial project schedules are expected development funding and expert judgment. More analytically based information, such as parametric modeling, historical similar programs, bottom-up schedule development, and comparable commercial programs, have significantly less influence on project schedules. The primary tools used to develop initial project schedules are the basic milestone and Gantt charts. The more sophisticated Critical Path Management and PERT are rarely used extensively, though many programs report using those tools occasionally.

The initial project schedule sets the stage for further acquisition planning and approval, which in turn leads to the contracting phase. The impact of a project's initial schedule on contractors' proposed schedules and actual contracted schedules is addressed in the next chapter.

Chapter 9

The Impact of a Project's Initial Schedule on the Contracting Process

Defense contractors accomplish nearly all Air Force development projects. The contract established between the Program Office and the company describes what needs to be done and when it needs to be completed. This contracted schedule is developed from the government's initial schedule and the contractor's proposed schedule, which is in turn affected by schedule-related incentives from the Program Office. As will be shown in Chapters 10 and 11, the contracted schedule plays the central role in determining the time it takes to develop a project.

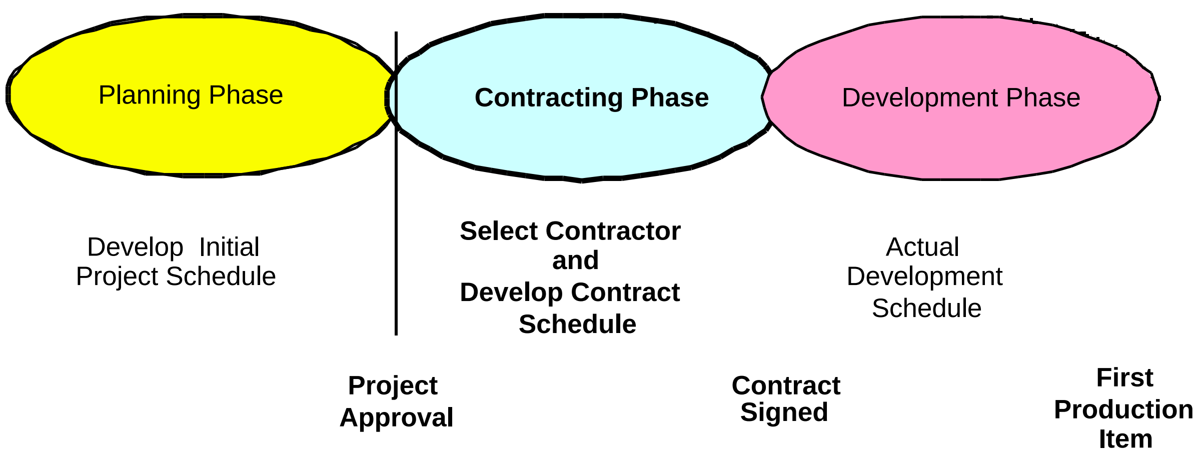


Figure 9-1: Development of the Contract Schedule During a Project's Contracting Phase.

A. The Expected Schedule Included in the Request for Proposals

A significant number of projects publish an expected schedule as part of the request for proposals (RFP). To determine how often that occurs, the Pentagon survey asked if the project had, through its RFP or other means, specified an expected schedule to potential contractors. Of those respondents, 80 percent said that the Program Office had established an expected schedule for the contractors.

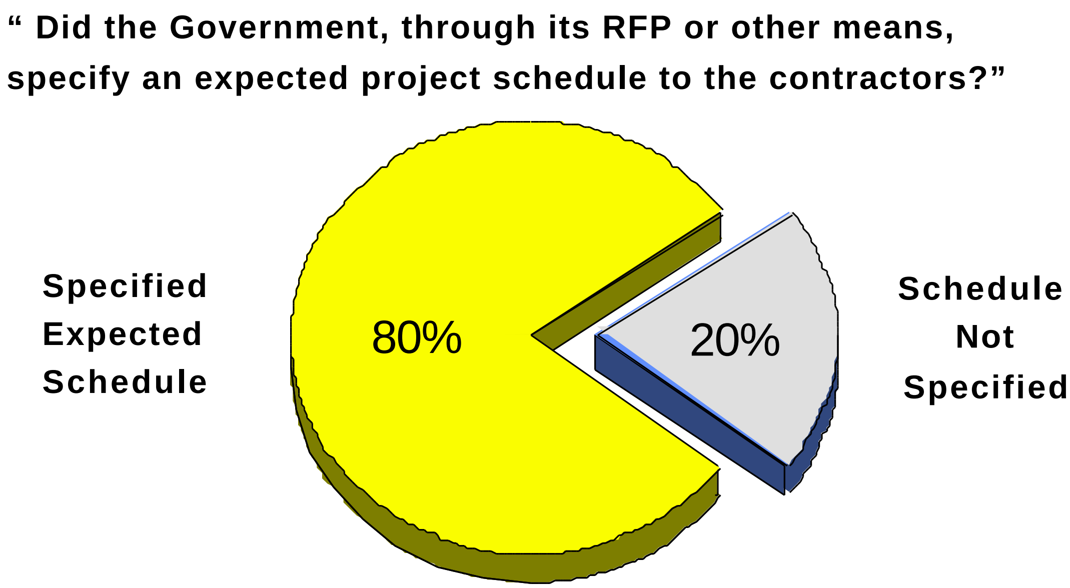


Figure 9-2: Percentage of Projects Reporting a Project Schedule Specified to Contractors. (Pentagon Survey; Number of Projects = 48).

These results are consistent with those in a master's thesis completed under the purview of the Air Force Institute of Technology. Richard Hazeldean and John Topfler found that 20 of 25 development contracts they studied at Wright-Patterson Air Force Base were "pre-scheduled," and had included an expected schedule in the request for proposal.[98]

Before examining the effect of the government's projected schedule, it is useful to look at

[98] Richard Hazeldean and John Topfer. Contracting for Schedule Performance. Air Force Institute of Technology. AFIT/GSM/93S-7 Wright-Pattterson Air Force Base OH. Pg. 4-10.

contractors' view of their ability to influence project planning prior to release of the RFP.

B. Contractor's Ability to Influence the Request for Proposals

The contractor survey asked respondents to rate their company's influence on various aspects of the project prior to release of the RFP. The contractors reported having the most influence on the project concept. They reported significantly less ability to influence the system performance requirements, and even less ability to influence project schedules. The contractor's influence on trade-offs among performance, cost, and schedule; program funding levels; and the project's acquisition strategy fell in the lowest statistical group.

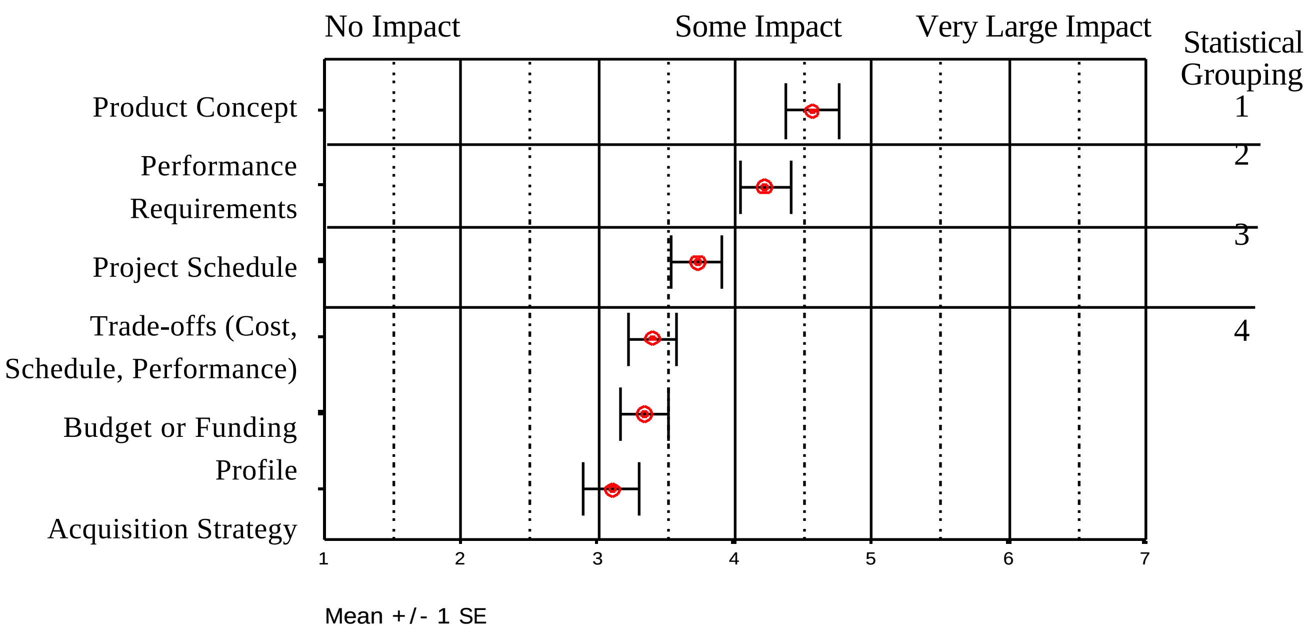


Figure 9-3: Contractors' Reported Ability to Influence a Government RFP Prior to Its Release (Number of Projects = 99).

On average, contractors report having less than "some impact" on the government's schedule development prior to RFP release. The Program Office survey indicated that contractors were the third most important organization affecting project schedule development. Results of the Pentagon survey ranked contractors fifth in influence on development schedules.

The type of contract award appears to have a significant impact on contractors' ability to influence a program. Contractors with competitively awarded contracts appear to have dramatically less influence on a project's schedule, as well as on the projected budget profile and acquisition strategies. No statistical differences were noted in contractors' abilities to influence performance requirements, product concept, or the trade-off among cost, schedule, and performance, based on type of award.

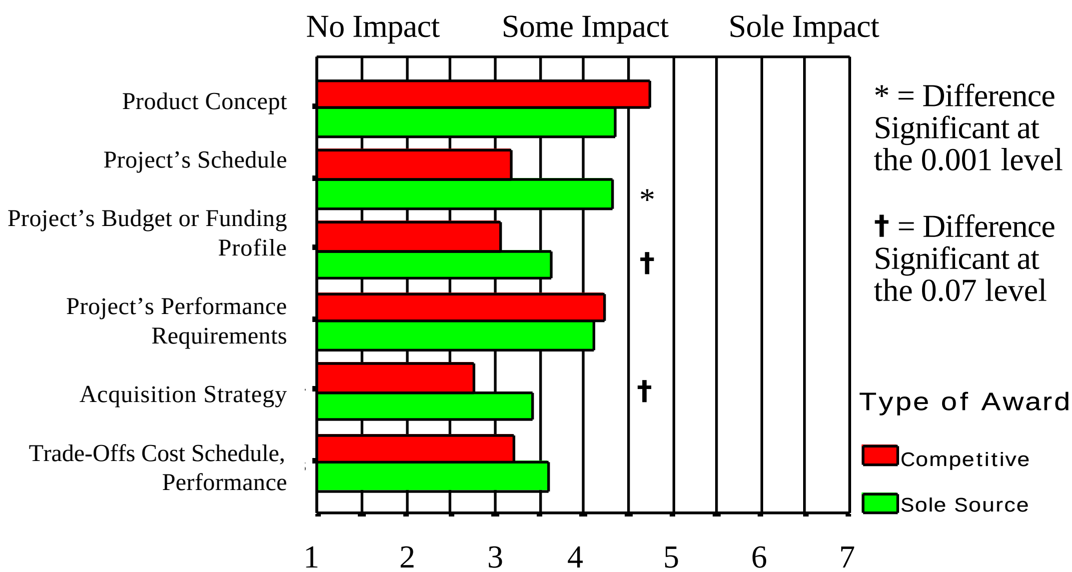


Figure 9-4: Impact of Competition on a Contractor's Ability to Influence Various Aspects of a Project (Statistical Differences Determined Using the Wilcoxon Signed-Rank Test).

C. Contractor Schedule Inputs

If contractors have little ability to influence the government's expected schedule prior to RFP release, what impact does that schedule have on the contractor's proposed schedule? In developing a proposed schedule, contractors consider many factors. The contractor survey asked respondents to rank five such factors from "no impact" to "sole determinant." The customer's desired schedule was reported to have the largest impact on contractors' proposed schedules by a wide margin. The factors associated with the actual development requirements, including expert judgment, bottom-up schedule development, historically similar programs, and comparable commercial development, were all rated significantly lower than the customer's desired schedule. Thirty-two percent of respondents indicated that the customer's desired schedule was the "sole determinant," and another 34 percent selected the next-highest rating. None of the other factors, including "expected funding availability," "expert judgment/bottom-up schedule development," and "historically similar programs," averaged above "moderate impact."

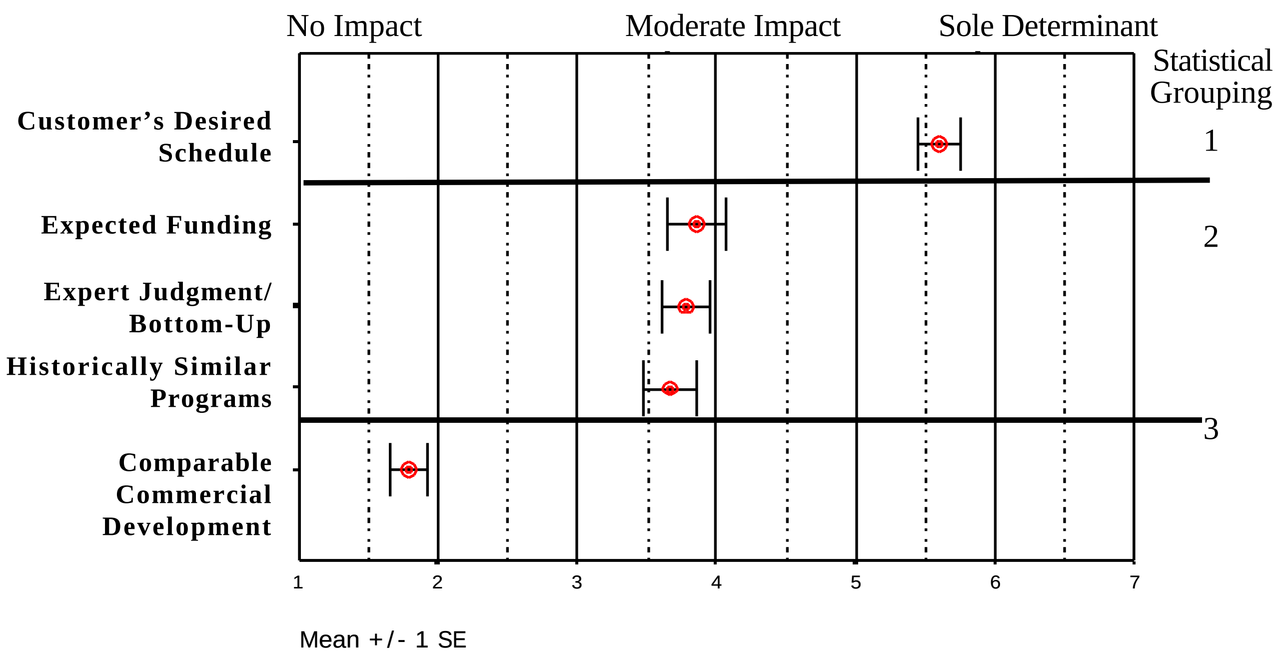


Figure 9-5: Impact of Various Factors on a Contractor's Proposed Schedule (Contractor Survey; Number of Projects = 96).

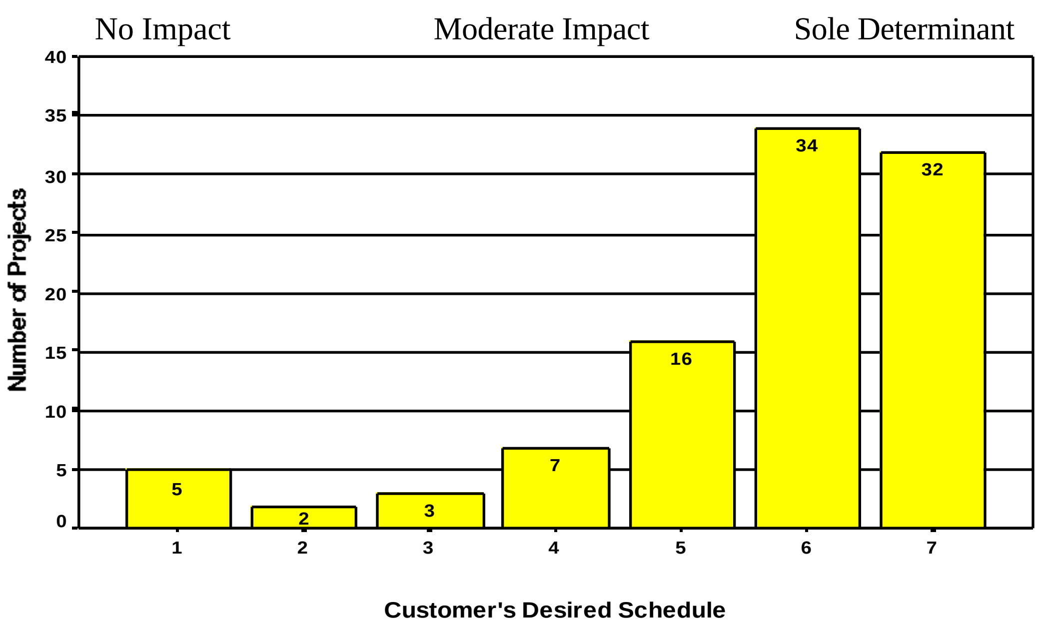


Figure 9-6: Impact of Customer’s Desired Schedule on Contractor-Proposed Schedule (Contractor Survey; Number of Projects = 99).

Project characteristics such as product type (aircraft, spacecraft, electronic system, or munitions), product size (ACAT level), and acquisition phase did not have a significant impact on the reported contractor schedule inputs. The type of contract selection (sole source or competitive source) also did not have a large impact on the contractor’s schedule development. The customer’s desired schedule was rated slightly higher for competitive procurements than for sole-source awards, but the difference was statistically significant at only the 0.15 confidence level. Contractors on both types of contracts reported primarily using the customer’s desired schedule.

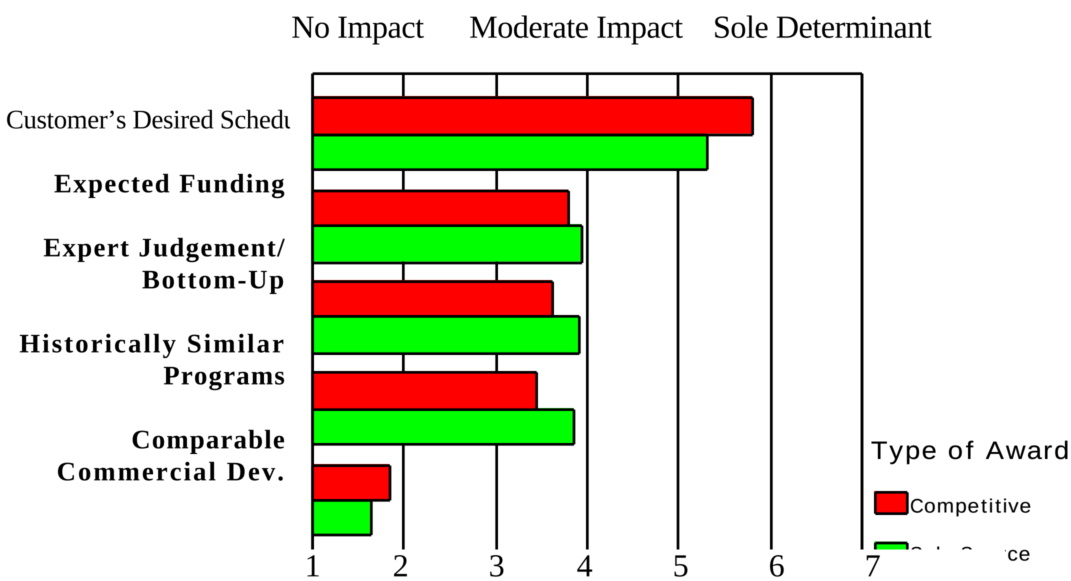


Figure 9-7: Effect of Competition on Contractor Schedule Inputs by Type of Contract Award (Contractor Survey; Number of Projects = 96).

Comparable commercial development projects were rated as having the lowest impact on the contractor’s proposed schedule, and appeared not to play any significant role in most projects: 61 of 96 reported “no impact.” Overall, 81 percent of respondents chose one of the two lowest categories. Comparable commercial development efforts were rated higher than expert judgment in 5 of 95 cases, higher than historically similar programs in 2 cases, and higher than expected funding in 2 cases.

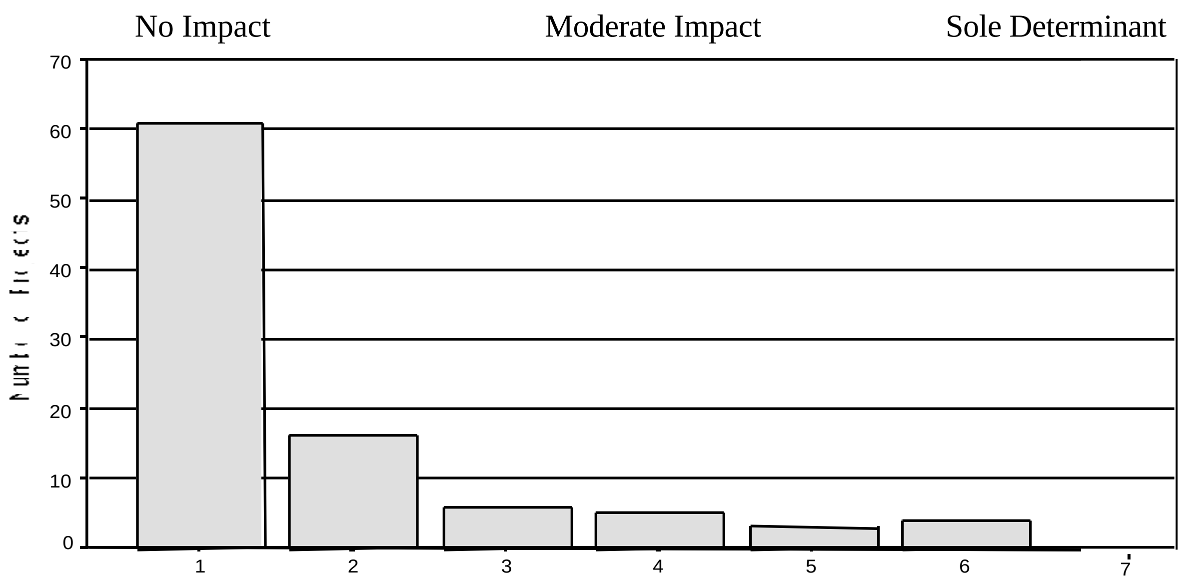


Figure 9-8: Impact of Comparable Commercial Development on a Contractor's Proposed Schedule (Contractor Survey; Number of Projects = 96).

The very low impact of comparable commercial efforts would imply that such efforts are not relevant to military projects. However, responses to other questions indicate that it is not the technology of military projects that separates them from commercial projects.

To determine the relevance of commercial development efforts, both the contractor and Pentagon surveys asked if the key enabling technologies used in the projects had existing commercial markets. Among 162 projects, 68 percent reported at least "some commercial markets" for key enabling technologies used in the project. In a separate question, the Program Office survey asked whether technologies used in the project had more demanding requirements than commercial technologies, and whether the system should therefore take longer to develop and field. Forty-three percent did not agree, indicating that they believed projects they were working on should not take any longer. An additional 29 percent indicated that they "somewhat agreed," while 29 percent indicated that they "strongly agreed" that the projects should take longer to develop.

These results indicate that in many cases commercial development efforts use similar technologies. The results also indicate that factors other than technology underlie the low impact of comparable commercial projects on schedules for military projects.

D. Contractors' Incentives and Source Selection Criteria

With contractors reporting that the customer's desired schedule is the dominant influence on their proposed schedule, it was important to determine the schedule-related incentives that contractors experience. The surveys thus attempted to determine the importance of the development schedule in selection of a contractor, and the incentives for contractors to propose alternative schedules. During proposal development, a company's primary objective is to be selected for the contract. Failure likely means exclusion not only from development but also from production and long-term support activities.

The Program Office and Pentagon surveys queried respondents on the importance of the development schedule in choice of contractor. Among program managers, 78 percent listed development time as "somewhat important" or "not important" as a source selection criterion. Fully 30 percent identified development time as "not important," while only 22 percent identified it as "very important."

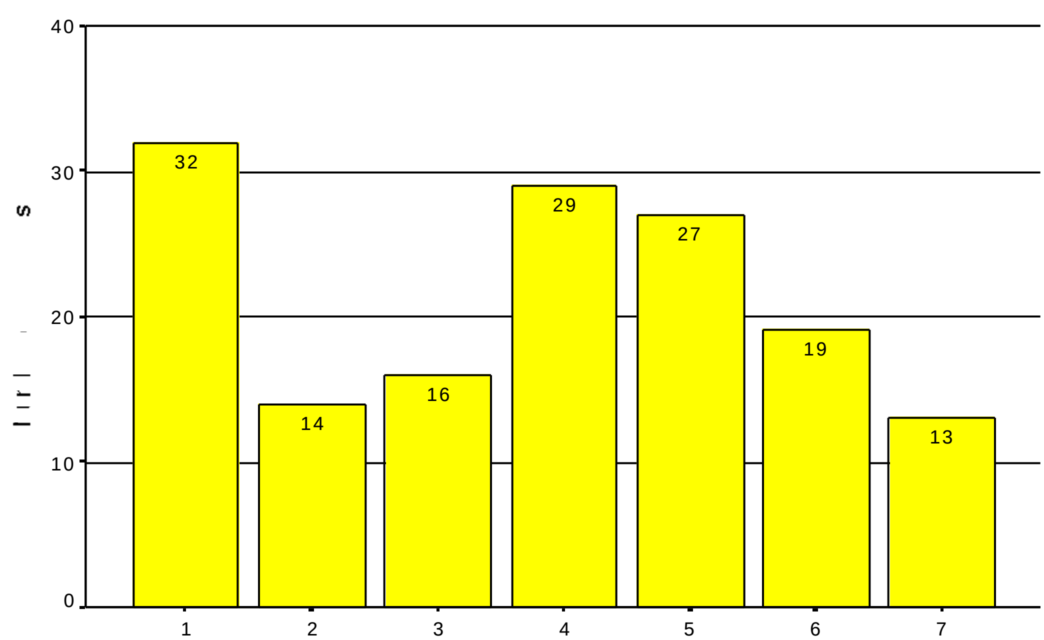


Figure 9-9: Importance of Development Time as a Source Selection Criterion (Program Office and Pentagon Surveys; Number of Projects = 150)

To determine the impact of source selection criteria on contractors as they develop their proposals, the Contractor Survey asked respondents to indicate their net incentive to bid a schedule different from that proposed by the government. Sixty percent responded that they had "no incentive" to bid a different schedule, while 15 percent indicated that they had a negative incentive. Only 25 percent indicated a positive incentive, and just 6 programs indicated a strong incentive to bid a different schedule. The responses reveal that contractors feel little incentive to bid schedules other than what Program Offices expect.

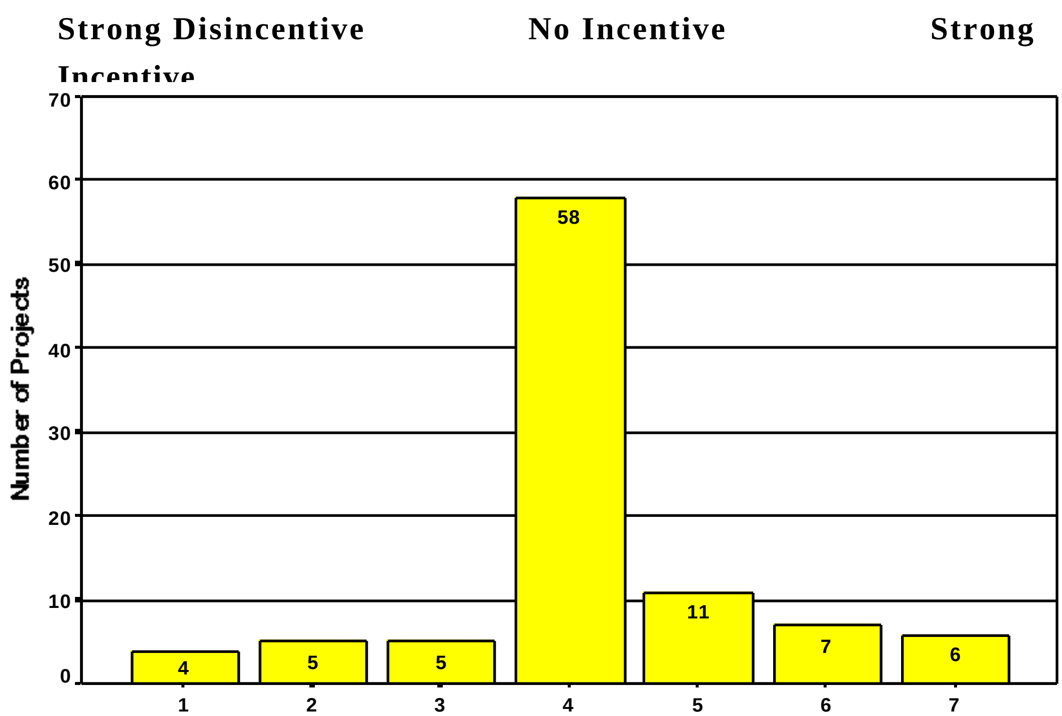


Figure 9-10: Contractor's Incentive to Bid a Schedule Different from the Expected Schedule (Contractor Survey; Number of Projects = 96).

There may be several explanations for the fact that contractors do not view development time as an important selection criterion, including the lack of overall priority given to development schedules, as shown in the last chapter. However, experience in the commercial market might suggest that competition would increase contractors' incentives to reduce time to market and bid a shorter schedule. But the survey results indicate that the opposite is true: contractors involved in competitive source selections report that they have less incentive to submit a proposal schedule different from the government's estimate. In both sole-source and competitive selection, there appears to be little incentive to bid a schedule different from what Program Offices expect. Competition based on time to market does not generally appear to occur in defense development projects.

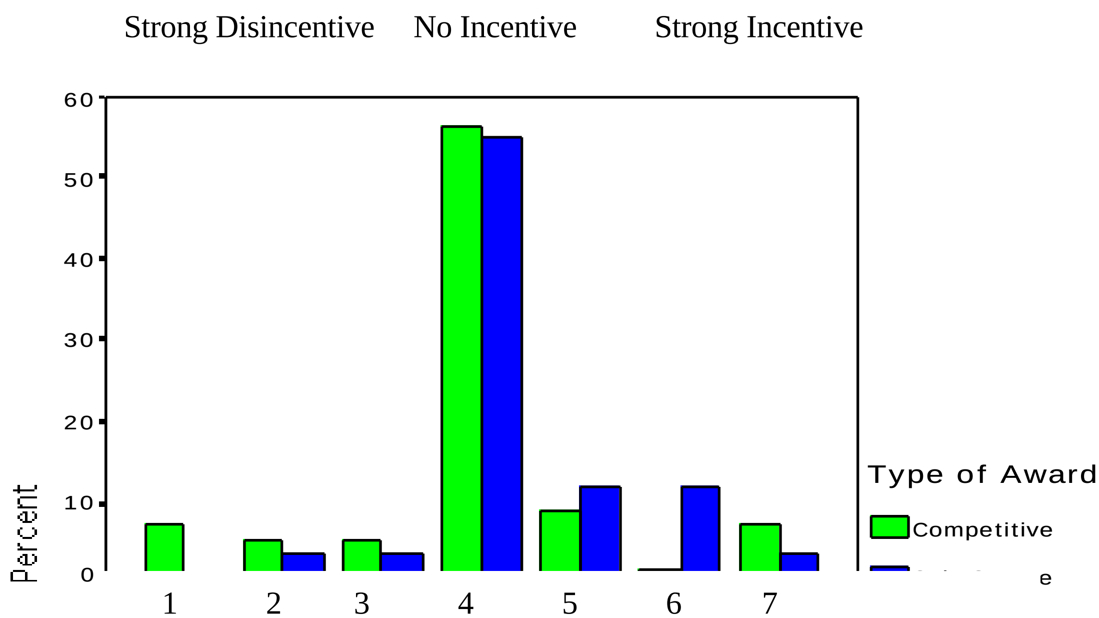


Figure 9-11: Distribution of Reported Contractor Incentive for Bidding Different Schedules, for Sole-Source and Competitive Awards (Contractor Survey; N = 96).

During follow-up interviews, several contractors expressed surprise that incentives to bid a different schedule were even this high: they believe there is generally a strong disincentive to bid different schedules. The reason they provided is that the Program Offices believe *they* understand how long it will take to develop the project, and if contractors bid different schedules they are seen as higher-risk or non-responsive. This attitude is seen in companies' guidance to proposal development teams outlined in Chapter 3. Such guidance emphasizes that telling Program Offices they are wrong "is not a winning strategy."

Contractors often have the option of submitting an alternative proposal in response to an RFP. Several interviews with Government program managers at the Aeronautical Systems Center and the Electronic Systems Center, however, revealed that Program Offices rarely consider alternative proposals. Interviewees believed that submitting an alternative proposal split the contractor's proposal preparation effort and resulted in two lower-quality proposals, each with a smaller chance of selection. Contractors also stated that submitting two proposals might indicate that the company could not make up its mind, revealing a lack of ability to make hard decisions. They stated that the typical approach is to submit the proposal that stands the highest chance of being selected, and then to discredit the other approach in case a competitor has selected that approach. Such "ghosting " of non-selected approaches is also documented in one company's proposal development guide.

Interviewees at the Aeronautical Systems Center stated that an RFP often forbids alternative proposals, and that when not forbidden they are rarely encouraged. They stated that proposals not meeting the expectations of the Program Offices are viewed with suspicion and generally automatically perceived to have higher risk. They also stated that for a company's alternate proposal to be considered, its primary proposal would have to be in the competitive range and stand a good chance of being selected.

E. Resulting Contractor Proposals

Any effect of schedule incentives would appear in contractors' proposals. The Contractor survey asked respondents to quantify the difference between their company's proposed project schedule and the Program Office's expected schedule outlined in the RFP. Of 83 respondents, 62 or 75 percent said their proposed schedules matched the length of the Program Office's planned schedule exactly.

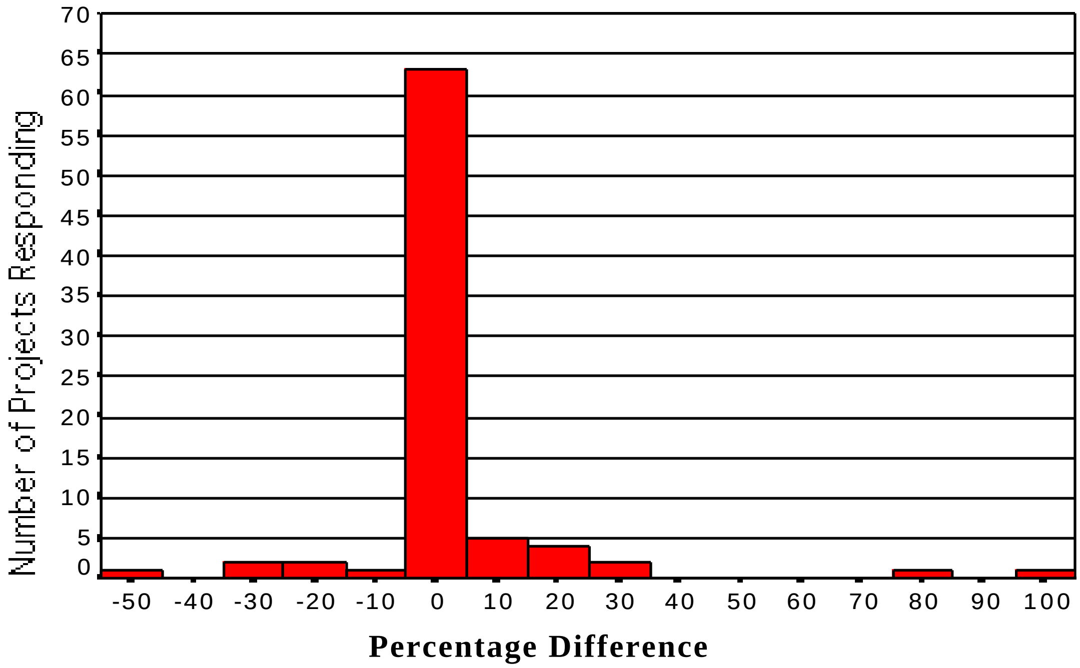


Figure 9-12: Difference Between Winning Contractor's Proposed Schedule and the Government's Expected Schedule (Contractor Survey; N = 83).

The responding contractors do not represent all the companies that bid on the projects, only those that won contracts. To examine the larger set of all bidding companies, the Program Office survey asked respondents to identify all the proposals received. Of the 282 proposals reported, only 32 were shorter than the government's planned schedule by more than 5 percent. Some 194 were within 5 percent, and 56 were longer than the government schedule by more than 5 percent.

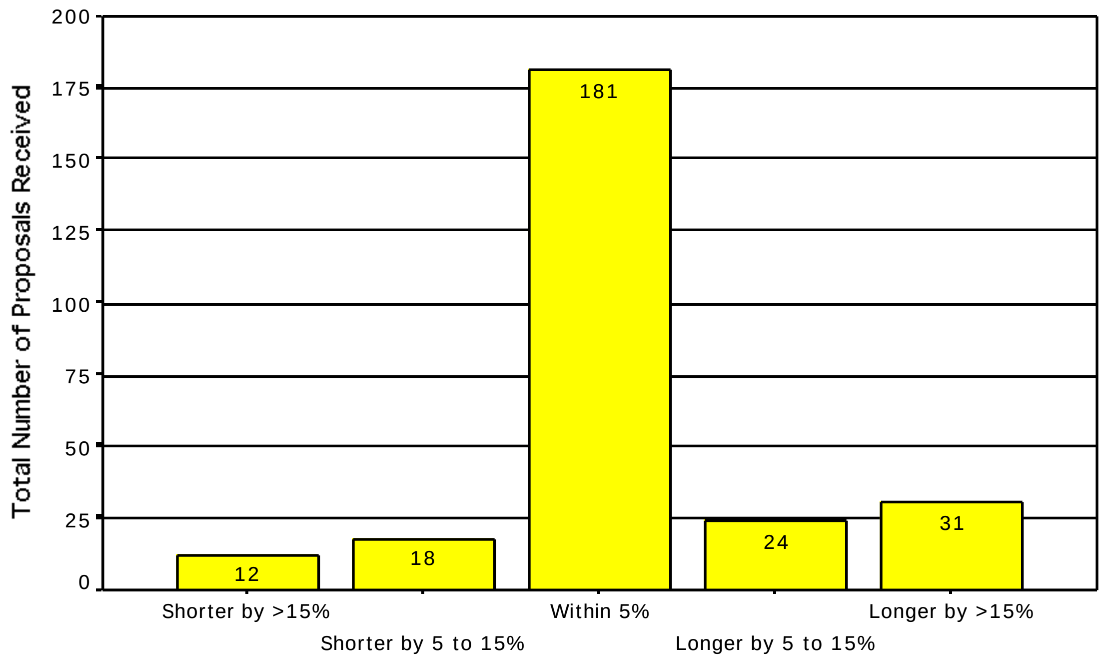


Figure 9-13: Proposals Received by Program Offices Compared with Their Expected Schedule (Program Office Survey; Number of Projects = 83).

The Pentagon survey found similar results. Of the 30 Pentagon respondents who had completed the source selection process, all but 6 selected contractors who bid exactly the schedules expected by the Program Office. Four of the 6 winning contractors who bid different schedules bid shorter schedules, while 2 bid longer schedules.

The effect of competition on contractors' proposed schedules is opposite to what would have been expected from commercial experience. On average, contractors participating in a competitive selection process proposed project schedules 4.5 percent longer than the Program Office estimate. Schedules from contractors operating in a sole-source environment were 3 percent shorter, on average, than the Program Office estimate. However, while this difference is significant at the 92 percent level using the independent samples t-test, caution should be taken as the number of projects bidding different schedules is small. A vast majority of both competitive and sole-source proposals are no different from the Program Office's expected schedule.

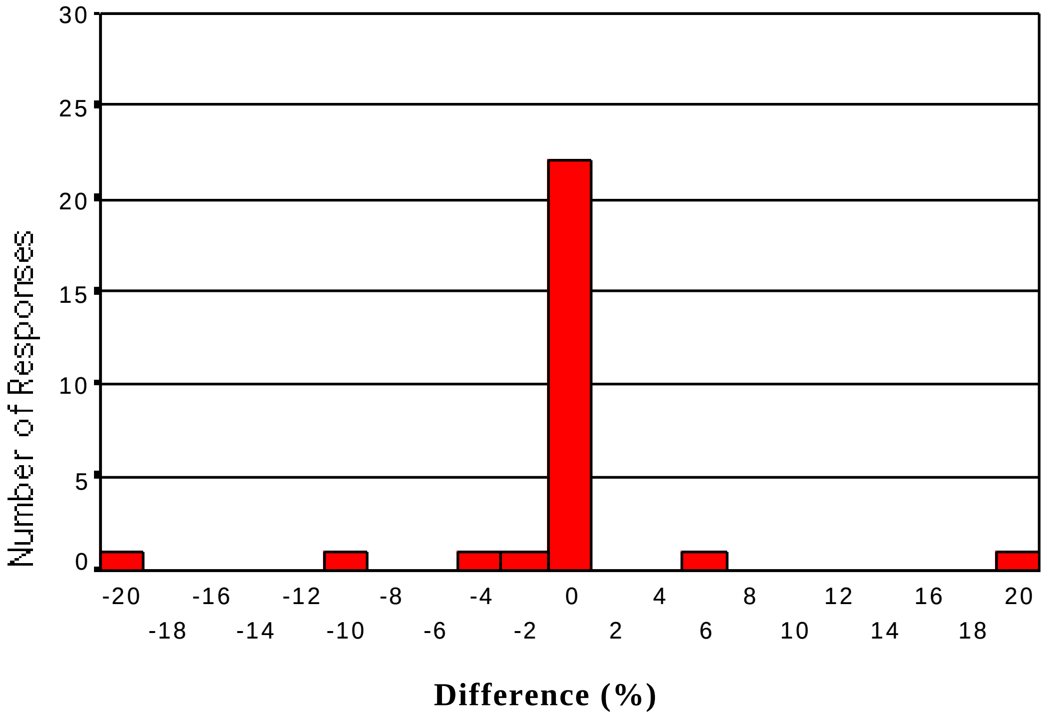


Figure 9-14: Percentage Difference between the Winning Contractor's Proposed Schedule and the Program Office's Expected Schedule (Pentagon Survey; Number of Projects = 32).

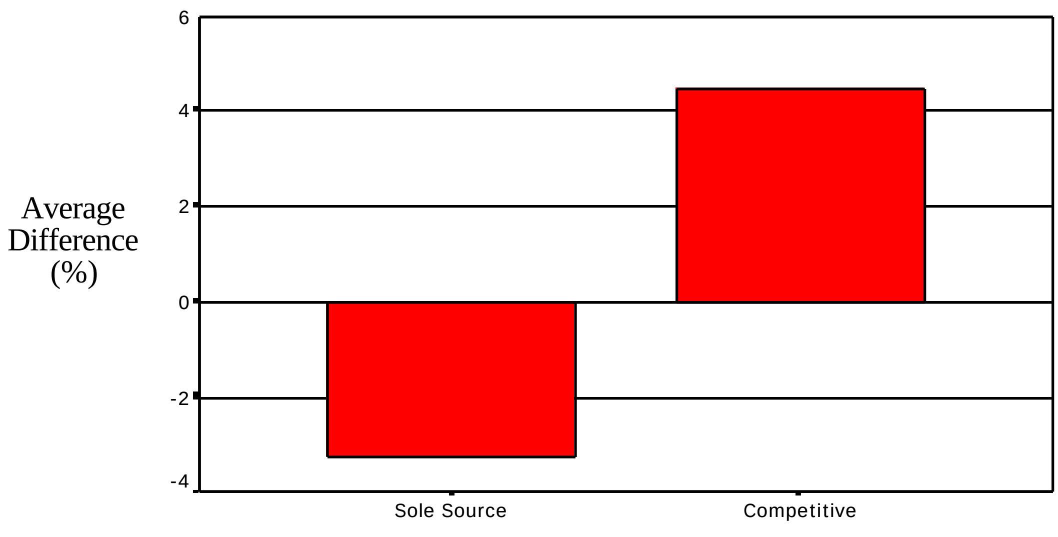


Figure 9-15: Percent Difference between the Program Office's Expected Schedule and the Contractor's Proposed Schedule for Competitive and Sole-Source Awards (Contractor Survey; Number of Competitive Contracts = 44; Number of Sole-Source Contracts = 39).

Summary of Contracting-Phase Schedule Results

During the contracting phase, the Program Office selects plans for the development project as well as a contractor to execute them. This is done through a request for proposals on which contractors bid. The contracted schedule between the Program Office and the winning company is very important, as it details what the contractor is to accomplish and when.

Development of the contract schedule is driven primarily by the project's initial planned schedule and not by other factors. Overall 80 percent of projects specify an expected schedule to contractors. A contractor's primary consideration in proposing a project schedule is the Program Office's desired schedule. The company's development capabilities are given much less consideration. When developing a proposed schedule, contractors report no incentives to bid anything other than what the government has requested. Program Office and Pentagon respondents report that short schedules are not an important source selection criterion, and do not give a contractor any advantage in that process. Bidding a schedule different from what is expected increases the perceived risk to the government and the contractors. Because companies that bid a different schedule are considered "non-responsive" to the RFP, they are less likely to be selected. Thus industry parrots back government-estimated schedules with few changes. From these contractor proposals the Program Offices select the winners and award the contracts.

As was shown in the previous chapter, a project's initial schedule is determined primarily by the available funding. The overall result of the planning and contracting phases are that contract schedules are based primarily on the Program Office's interpretation of a project's funding constraints, not on its development-related requirements or the contractor's product development capabilities.

Chapter 10

Schedule Incentives During the Development Phase

Awarding the development contract marks the end of the contracting phase and the beginning of the development phase. The latter phase ends with the delivery of the first production item, marking the point when the vast majority of development-related activities are complete. Although the contracted schedule plays a significant role in setting product development times, it does not necessarily determine the amount of time it will actually take to develop a new system. Actual development times can be longer or shorter depending on many factors, including technical problems, funding constraints, and changing Air Force objectives. This chapter looks at the incentives for different organizations associated with project schedules from the time of contract award until delivery of the first production item.

To understand these incentives three surveys—of the Pentagon, Program Offices, and contractors—asked respondents to report the incentives to meet or exceed various project objectives they had experienced. A series of follow-up interviews with representatives from each group helped interpret and explain the results.

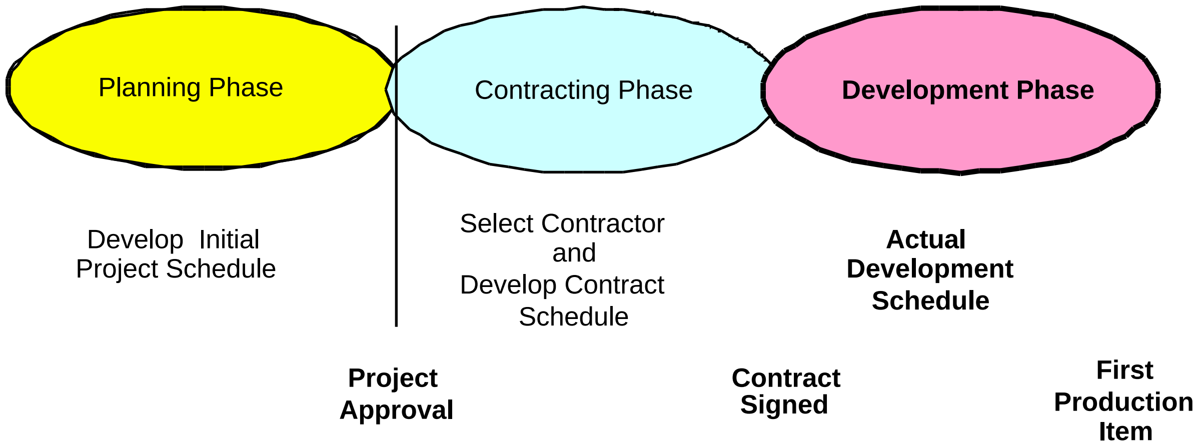


Figure 10-1: Project Schedules in the Development Phase.

A. Users' Incentives for Reducing Cycle Time

Because the surveys did not target the user community directly, Pentagon respondents, as the closest available surrogates, were asked a number of questions about users' incentives. Program element monitors and action officers are the spokespeople for users and projects within the Pentagon, and as such are expected to be aware of users' objectives and priorities. The responses indicate that users have a large incentive to meet a project's planned cost, schedule, and performance goals. The responses also indicated that many users have a significant incentive to exceed project goals in all aspects of cost, schedule, performance, and reliability. The incentives for increasing product reliability, reducing project schedules, cutting total project cost, enhancing technical performance, and reducing unit costs were all positive. The reported differences between various project objectives were not statistically significant.

Overall, Pentagon respondents indicate that 65 percent of users have a positive incentive to shorten a project schedule; 47 percent indicated that the users had a significant or strong incentive to shorten a project's schedule. Of those that provided a description of the schedule-related incentives for users, many mentioned the need for enhanced combat capability to meet operational objectives. Others mentioned the lower operational and maintenance costs promised by the new systems.

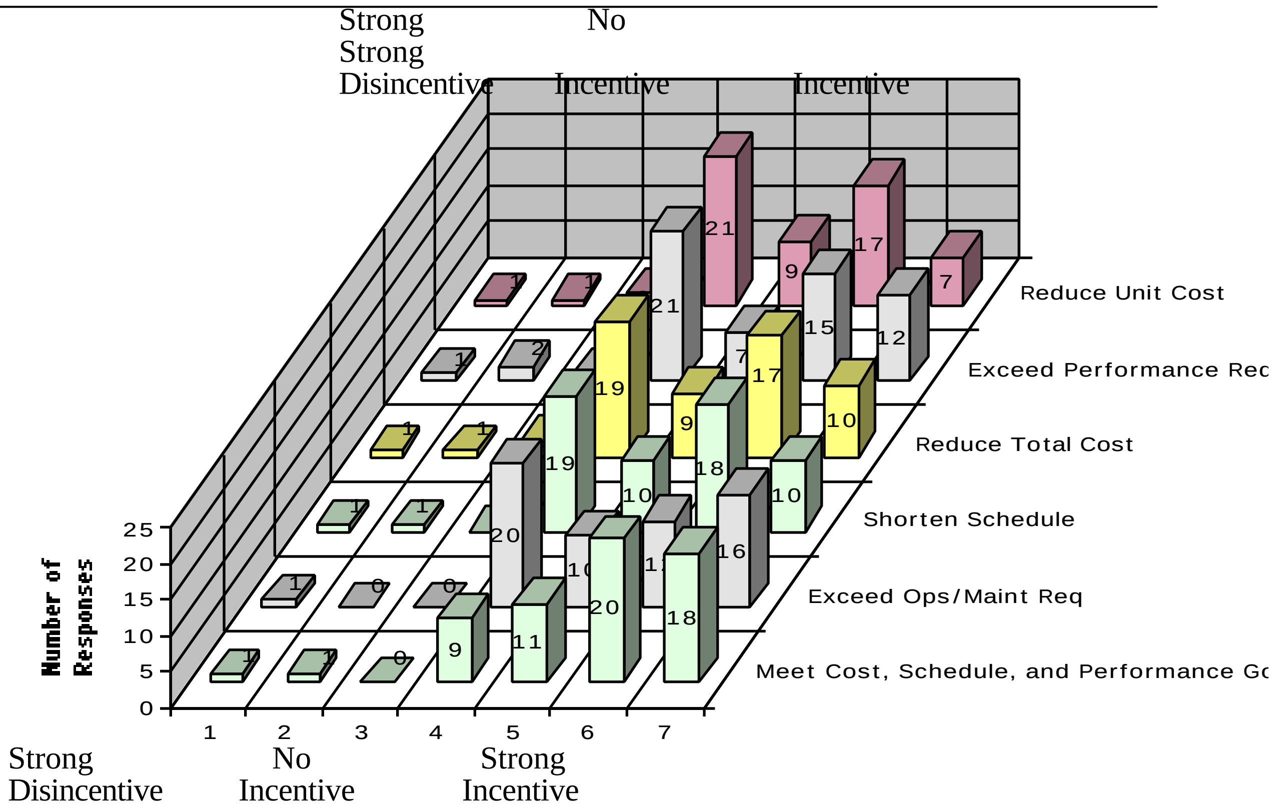


Figure 10-2: User Incentives to Meet and Exceed Project Objectives as Reported by Pentagon Survey Respondents (Number of Projects = 60).

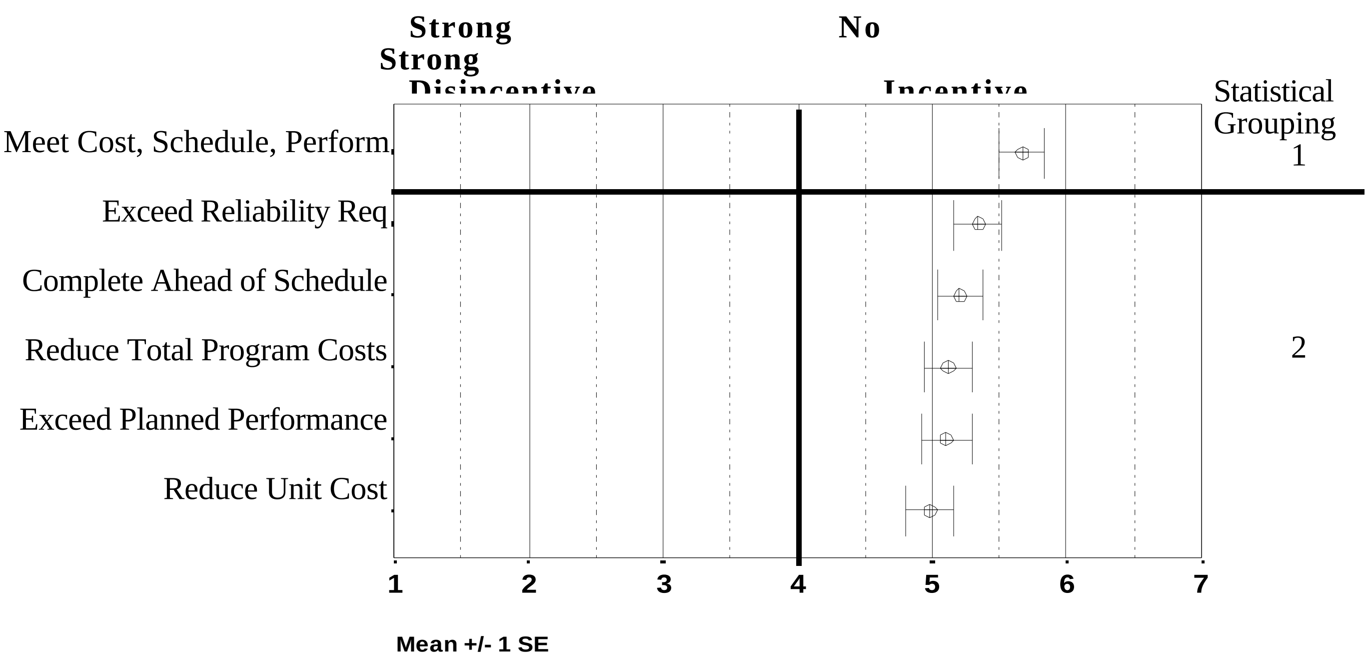


Figure 10-3: Average of Users' Incentives to Meet or Exceed Project Objectives (Pentagon Survey; Number of Projects = 60).

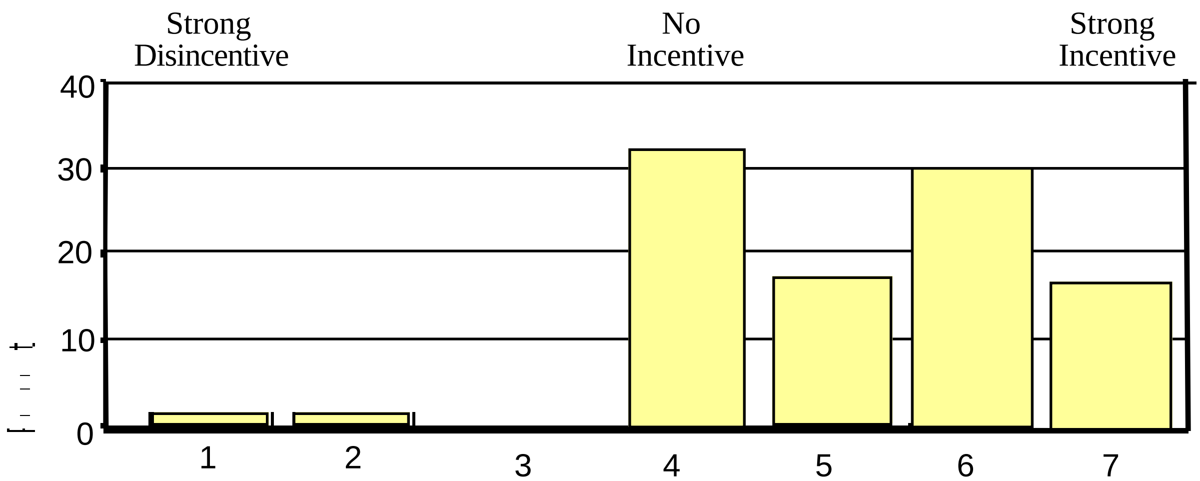


Figure 10-4: Users' Incentives to Reduce Development Time (Pentagon Survey; Number of Projects = 49).

B. Incentives for Reducing Cycle Time within the Pentagon

To determine the incentives within the Pentagon to meet or exceed project objectives, the Pentagon survey asked respondents to rate various project objectives as viewed by their organization, and as they viewed them personally. The survey also asked what impact meeting or exceeding project objectives had on their personal performance rating and their potential for promotion.

The survey asked respondents to rank-order four project objectives as viewed by their organizations: low acquisition cost, low operation and support cost, superior technical performance, and a short schedule to operational capability. The respondents most often rated superior performance as the first priority, low acquisition cost as the second priority, and low operating and maintenance costs as the third priority. Short schedule was most often rated as the fourth of four objectives, and rated significantly lower than each of the other objectives. A total of 65 percent of respondents listed short schedule as either the third or fourth of the four project objectives, while 42 percent rated short schedule as the fourth of four objectives.

Pentagon respondents were also asked to rank-order the four objectives as they personally viewed them to determine if their views differed from those of their organizations. Here the most important objective was reported as lowering a project's acquisition cost. Other objectives such as improving system performance, lowering operating costs, or shortening the schedule were rated significantly lower. Short schedule was statistically tied with low operating costs for last of the four objectives.

Given the low priority placed on shortening schedules compared with other objectives, it is unlikely that program element monitors or Air Staff action officers would push for reducing project schedules. They would be more likely to work toward achieving either what they view their organization wants or what they personally view as most important: improving performance or reducing acquisition cost. Shortening the schedule is not generally seen as an important organizational or personal priority.

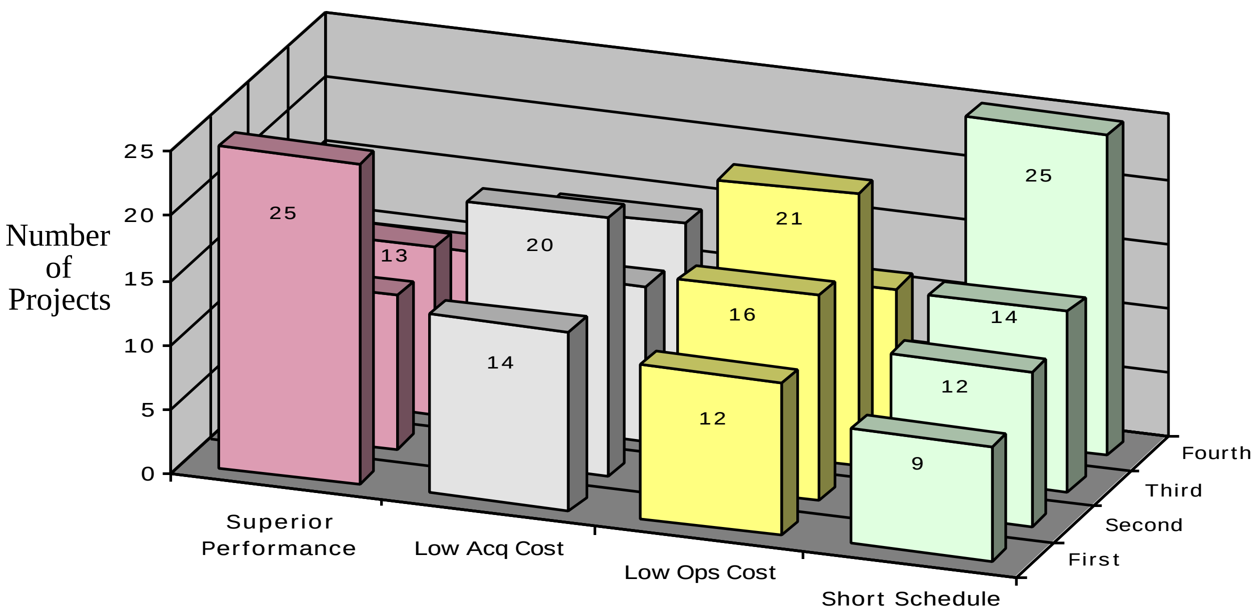


Figure 10-5: Perceived Project Objectives from Pentagon Respondents (Number of Projects = 60).

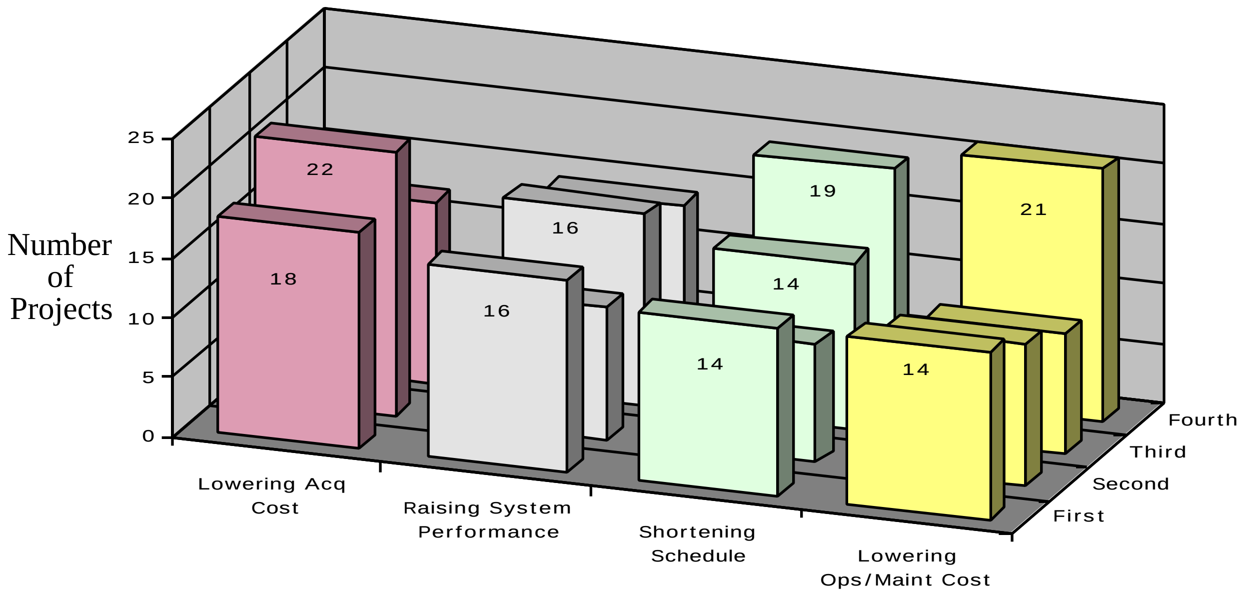


Figure 10-6: Respondents' Personal View of the Importance of Various Objectives to the Development Effort (Pentagon Survey; Number of Projects = 60).

The Pentagon survey also asked respondents to indicate how not meeting, meeting, or exceeding their project objectives affected their personal performance ratings and potential for promotion. The most frequent responses in each category indicated that the success or failure of a program has no impact on respondents' performance rating or potential for promotion. Overall, 85 percent replied that exceeding objectives would have only "some impact" or less on their performance ratings. And 75 percent stated that *not* meeting the project's objective would have some or small impact on their rating or potential for promotion.

In follow-up interviews, several program element monitors reiterated that the success of a project had little effect on their personal performance rating or potential for promotion, and indicated they felt that it *should not* affect their performance rating. Those interviewed felt that since they had little control over the success of a program, it would be unfair to rate them by the success or failure of the program. Some program element monitors seemed somewhat detached from their specific programs, indicating that they had to support what was good for the entire Air Force and could not just push for their specific program. Others were strong advocates and appeared very active in planning and executing a program. According to regulations, the program element monitor is the program's official representative, spokesperson, and advocate within the Pentagon. Several Pentagon-level respondents indicated that other factors such as appearance, hours worked, and responsiveness to requests for information were more important to their performance ratings than program success.

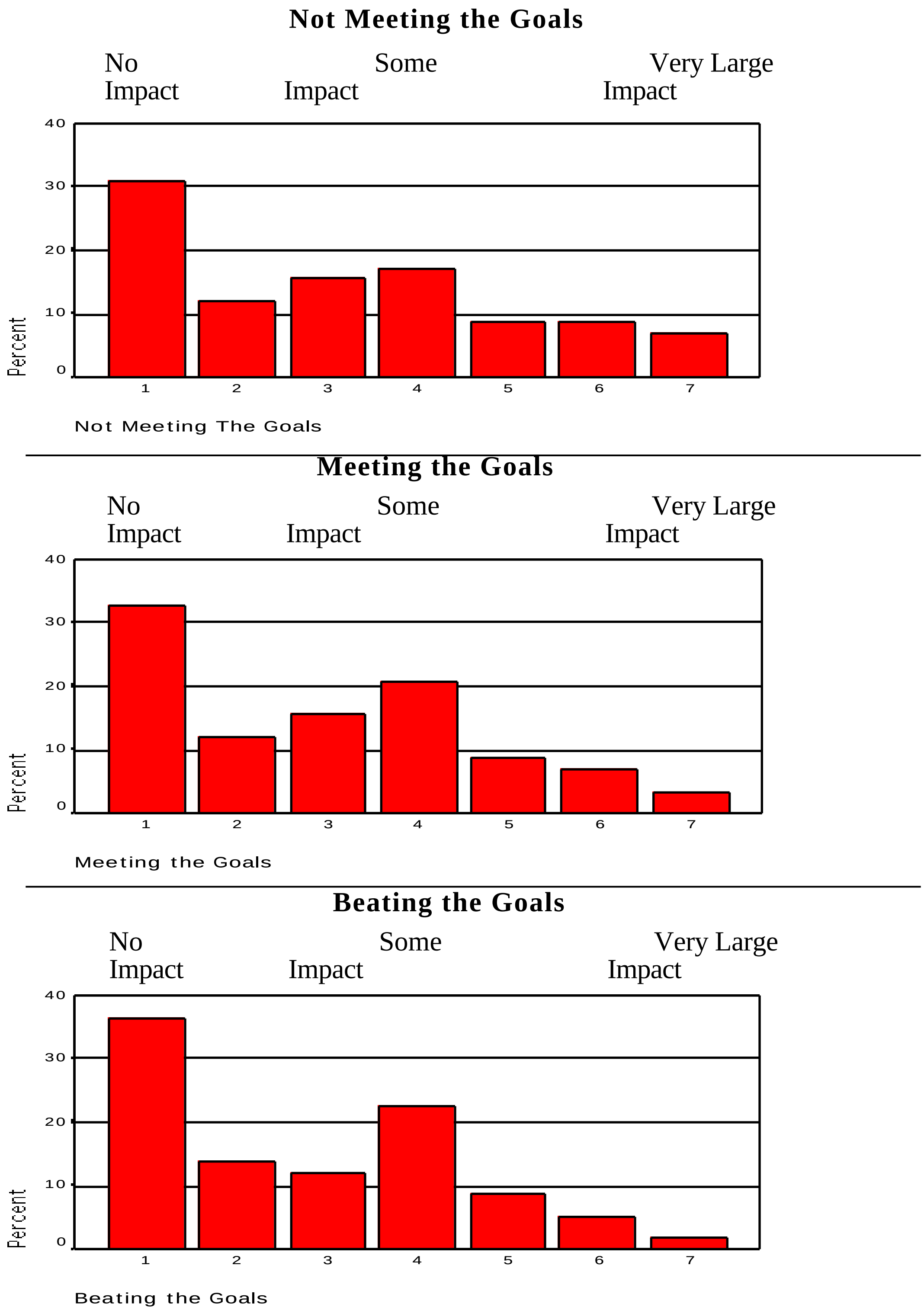


Figure 10-7: Pentagon Respondents' Perceived Impact of Not Meeting, Meeting, or Exceeding Project Goals on Personal Performance Ratings and Potential for Promotion (Number of Projects = 58).

C. Program Office Incentives for Reducing Development Time

The Program Office survey queried project managers about incentives to meet or exceed project objectives; whether short schedules were viewed as an important objective; and the effect of exceeding various objectives on their personal performance ratings. The Program Office survey also asked about the continuity and tenure of project managers and project staff. To determine incentives transmitted to Program Offices from organizations within the Pentagon, the Pentagon survey also asked respondents about incentives the Program Offices had to exceed various objectives. Again the results indicate few significant incentives for reducing project schedules in the Program Offices.

The Program Office survey asked project managers to rank-order four project objectives: superior technical performance, low acquisition cost, low operations and maintenance costs, and short schedule to operational capability. The largest number of project managers indicated that superior performance was the first project objective. Low acquisition cost was rated most often as second. Low operations and maintenance costs were most often rated as third. Shorter schedule was again most often rated as the fourth of four project objectives. Shortened schedule was rated significantly lower than superior performance and low acquisition cost, and roughly equivalent to low maintenance costs. As with Pentagon respondents, project managers are likely to focus on what they see as the first or second project objective. Any additional effort on the part of project managers is likely to be aimed at better performance or lower acquisition cost, and not at shorter cycle times.

Another question asked government project managers to what extent a short acquisition cycle was an important part of projects objectives. As shown in Figure 10-9, the distribution of responses was spread roughly equally from not important to very important. Managers of 36 projects, or 25 percent, indicated that short schedules were not important. Managers of 59 projects, or 41 percent, said short schedules were “somewhat important.” Managers of only 49 projects, or 34 percent, indicated that short schedules were an important project objective. Thus a substantial number (66 percent) of project managers do not see a short schedule as a particularly important objective for their projects, even when not competing against other project objectives.

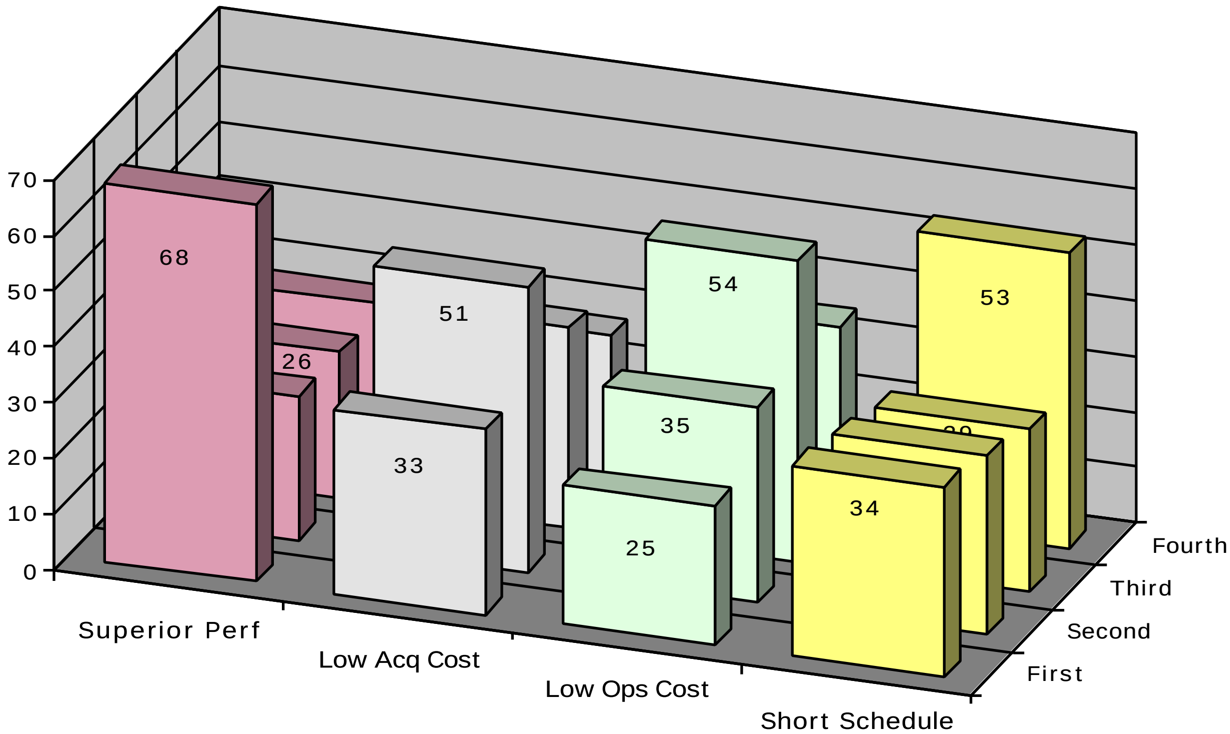


Figure 10-8: Ranking of Various Project Objectives by Government Project Managers (Program Office Survey; Number of Projects = 147).

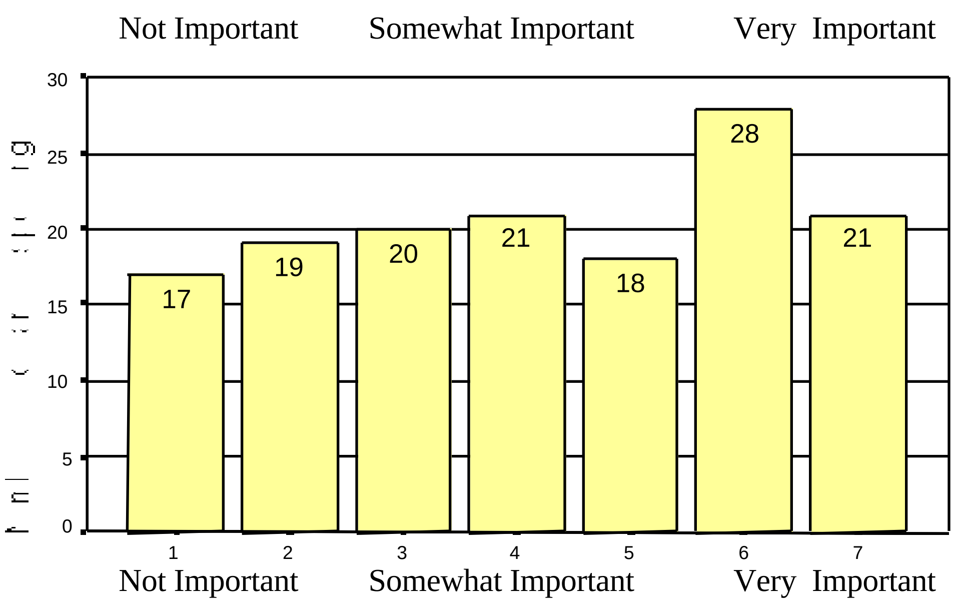


Figure 10-9: Number of Project Managers Reporting Short Acquisition Cycle as Very Important, Somewhat Important, or Not Important (Program Office Survey; Number of Projects = 144).

The Pentagon survey asked respondents to indicate the incentives for Program Offices to meet or exceed various project objectives. The Pentagon respondents indicated that the Program Offices have some incentive to meet project objectives but very little incentive to exceed them. The incentives for exceeding project objectives were reported to be significantly lower than those reported for users.

As shown in Figures 10-10 and 10-11, the program element monitors believe that the Program Offices' incentives for achieving a shortened schedule are significantly lower than for meeting the schedule. Only 20 percent of projects were reported with significant incentives to shorten schedule, and 23 percent with a slight incentive. Thus 58 percent of the projects were reported to have either no incentive (46 percent) or a negative incentive (12 percent) to shorten the schedule. Program Offices are seen as having a significantly stronger incentive to meet, as opposed to exceed, program objectives, with 80 percent of respondents indicating they had a positive incentive to do so.

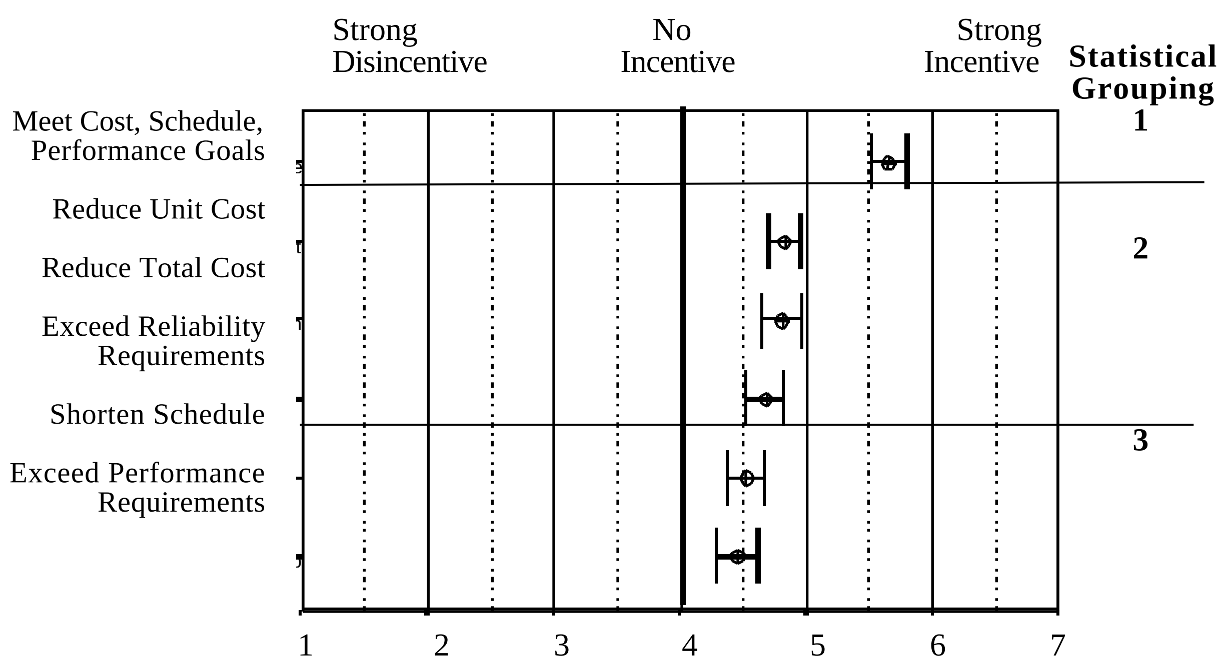


Figure 10-10: Pentagon View of Program Offices' Incentives for Meeting or Exceeding Project Objectives (Pentagon Survey; Number of Projects = 59).

Strong Disincentive

No Incentive

Strong Incentive

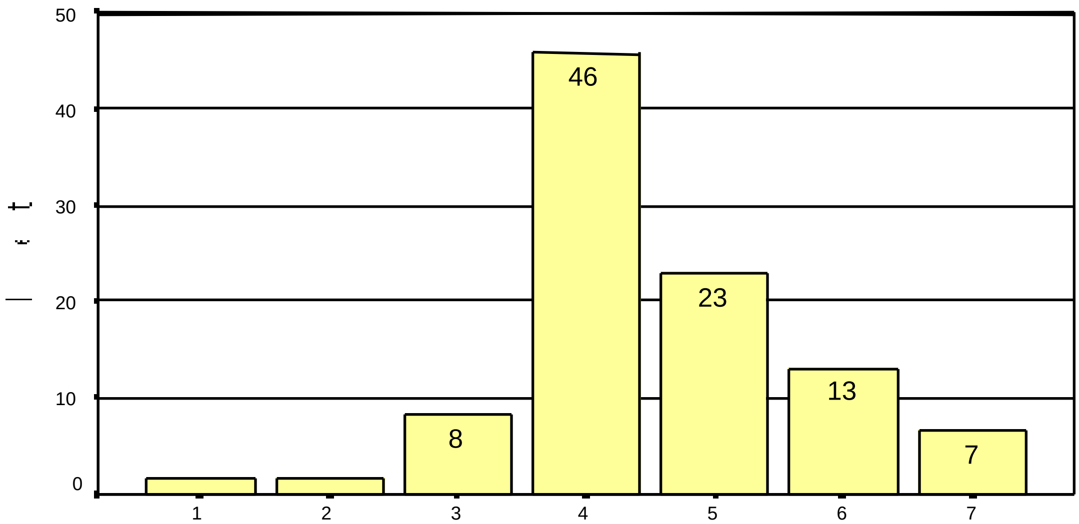


Figure 10-11: Pentagon View of Program Offices' Incentive to Reduce Development Time (Pentagon Survey; Number of Projects = 59).

The Pentagon survey asked respondents to indicate the form or type of incentive for Program Offices to achieve or exceed objectives. Very few responses indicated any specific, structured, or formalized incentive. Many mentioned oversight by leaders from the services and DoD as a motivating factor. Most others indicated "doing the right thing," individual initiative, and "patriotic duty" as the incentives. Few pointed to a specific organizational or individual financial, personal rating, or position-based incentive for Program Offices. Many indicated that the objectives of the program were to achieve their goals and not to exceed them.

To measure personal incentives, the Program Office survey asked project managers to rank-order various project goals—completing under budget, completing ahead of schedule, exceeding technical performance requirements, or exceeding operability/maintenance requirements—by their importance to their performance rating and potential for promotion. Meeting project goals was not included in this question as an option. Of the four objectives, finishing below cost was rated most often as having the most impact on project managers' performance ratings. Delivering a project ahead of schedule was most often rated as having the second-largest impact. As illustrated in Figure 10-12, exceeding operability and maintenance requirements was rated last on program managers' report by a wide margin, and was rated last by 55 percent of project managers. In the comment section or in the margins, many program managers wrote that the objectives were to meet the cost schedule and performance goals and not to exceed them.

One important note on the responses was that over 20 percent of the respondents took the time either to write comments that exceeding the objectives had little or no impact on their performance ratings or had marked all four objectives as the fourth and lowest priority. These observations were supported in interviews with program managers and with a separate group of junior acquisition officers. Many officers believe that the performance of their projects does not particularly affect their performance ratings.

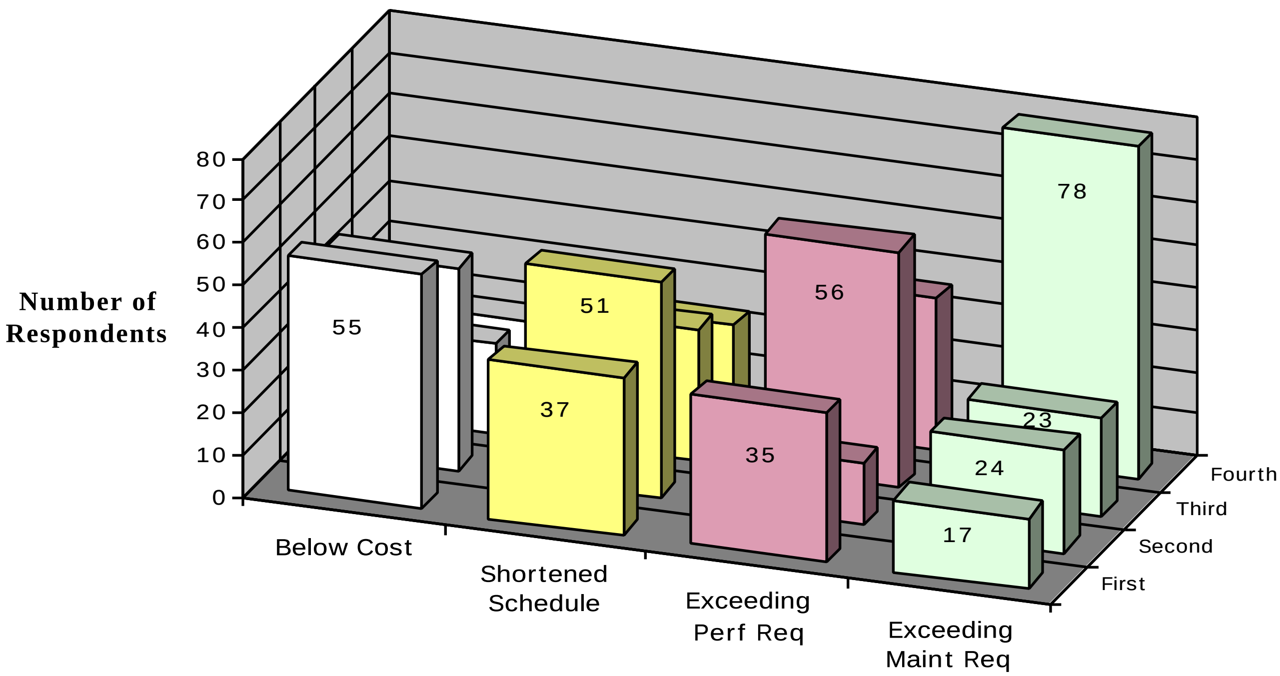


Figure 10-12: Perceived Effect of Various Objectives on Program Managers' Performance Ratings and Potential for Promotion (Program Office Survey; Number of Projects = 142).

Many senior acquisition officers commented on the surveys and in follow-up interviews that it is much more important to meet the expected schedule, no matter how long, than to try to achieve a shorter schedule and risk not fulfilling it. Success appears to be defined as meeting the planned schedule and not shortening it. Meeting the schedule was stated to be more important even if the project could be delivered earlier than originally planned. The perceived success of the program and the ramifications for the personnel involved focused on how the project met expectations, not on the time required to develop and field it. Managing expectations for the project was seen as a significant part of ensuring the project's perceived success.

An example of managing expectations was observed in a case study of a successful recent effort to develop a weapon system. The project received very high Air Force priority and its funding was not limited. Several earlier tests had already been conducted on prototypes, and the project relied entirely on proven technologies. Even in this case, the Program Office strongly resisted significant efforts by several senior leaders to shorten the project's initial schedule during the planning phase. This occurred despite the fact that the Program had strong evidence that a significantly shorter schedule was possible, and a contractor that pushed for and initially bid a significantly shorter schedule. The program manager stated that resisting the shorter schedule ensured that the project would meet the schedule and thus be seen as a success. The program manager bluntly stated that it was more important for this project to be considered a success even if the total time was significantly longer than to shorten the planned schedule and risk not meeting it. The extra time caused a two-year delay in integrating the weapon into the flight mission software of several fighter aircraft, as the schedule moved to a later biannual update. This significantly delayed initial operating capability on those aircraft, and the system was not ready during a threatened action against Iraq in the spring of 1998.[99]

During a discussion group with approximately 20 junior acquisition officers (captains and lieutenants), it was evident that the group felt the performance of the project they worked on had little impact on their performance ratings or potential for promotion.[100] Captains and lieutenants are typically assigned as project managers on smaller development projects. Several stated outright, and most agreed, that how they fulfilled their additional duties, such as organizing a unit party, had a larger effect on their performance rating than did the performance of their program.

One potential reason for this apparent lack of accountability is the short period that each project manager is in charge of a project. Some 65 percent of managers surveyed have been in charge of their projects for less than 18 months, and 47 percent have been in charge less than 12 months. The average tenure for managers of the 144 projects surveyed is 20 months. And this figure includes a number of civilian program managers, who typically stay significantly longer than their military counterparts. The average tenure is short compared with the average of 75 months from start to first production item for the same projects. The result is a large number of managers per project: 80 percent of projects surveyed have changed managers at least once, while 57 percent have had three or more project managers so far.

[99] "US Bombs Not Much 'Smarter.'" *Boston Globe*. Pg 1. February 20, 1998.

[100] The meeting was conducted with 20 officers at Hanscom Air Force Base in September 1996. It was intended to address the concerns of the junior officers in the acquisition-related career field.

A large number of project managers makes for difficulty in assigning decision-making responsibility. Even if responsibility for a decision can be assigned to a particular manager, he or she has often moved on before the results ensue. In fact, it is standard policy to ensure that younger officers, who often serve as managers on small projects, change Program Offices every 18 months to ensure that they experience different acquisition positions during a typical three-year assignment.

The survey data show not only that program managers change positions but that the entire staff rotates out as various projects proceed, undermining continuity. Figure 10-15 shows the percentage of original project staff remaining on a project. The Packard Commission report raised similar concerns 10 years ago.

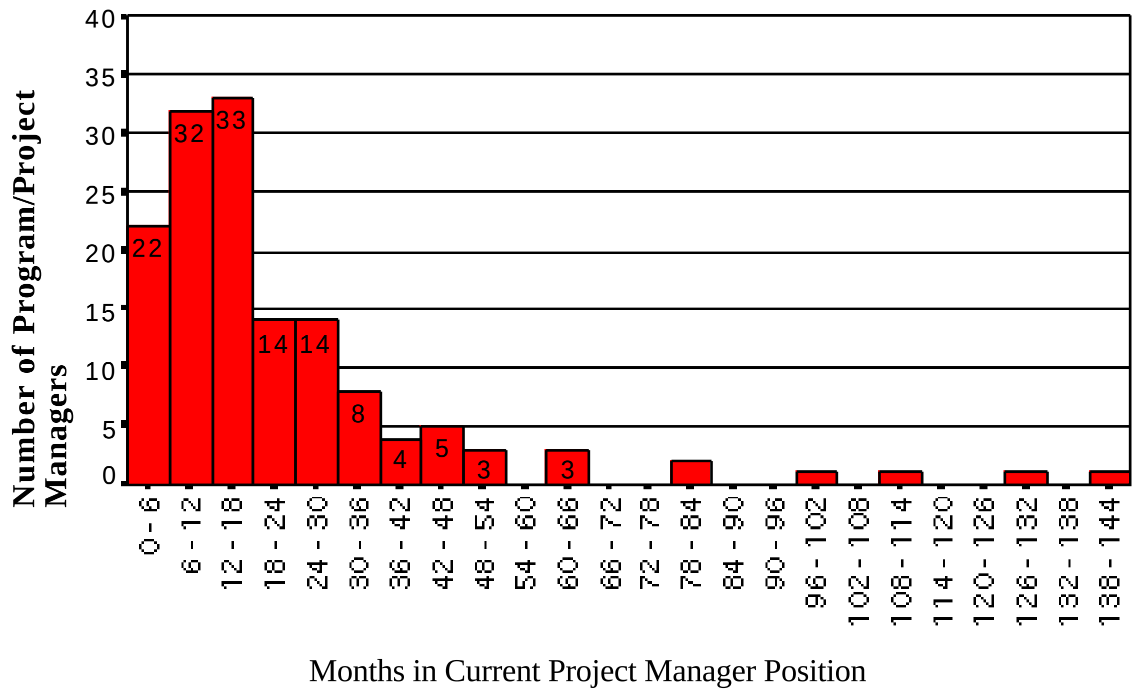


Figure 10-13: Project Manager Tenure in Current Position (Program Office Survey; Number of Projects = 144).

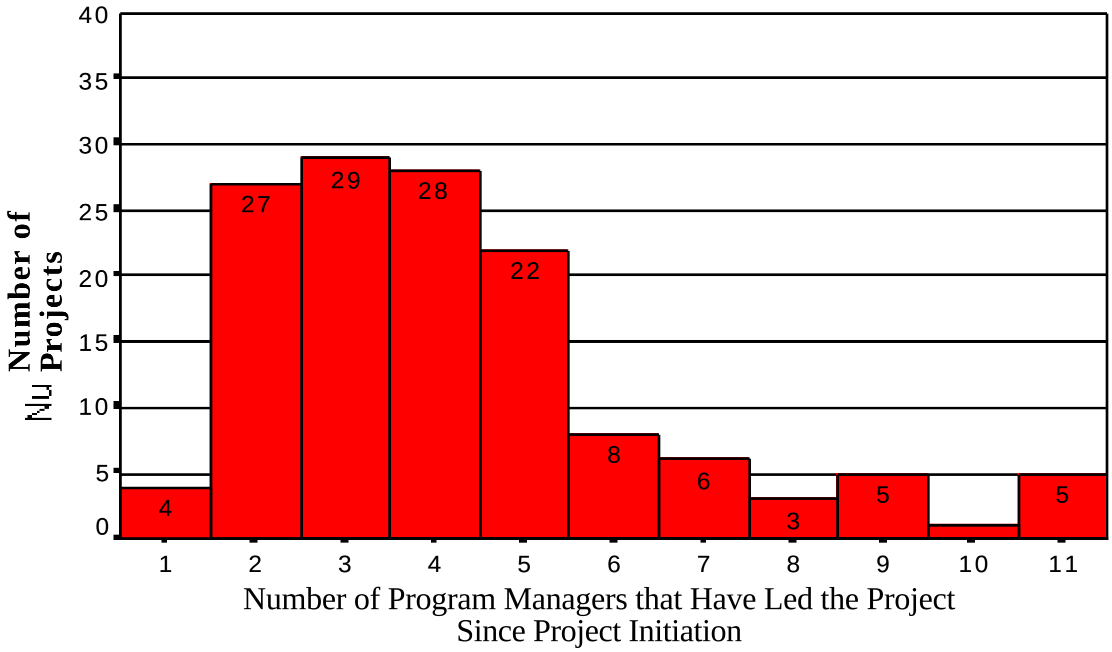


Figure 10-14: Number of Government Program Managers per Project (Program Office Survey; Number of Projects = 138).

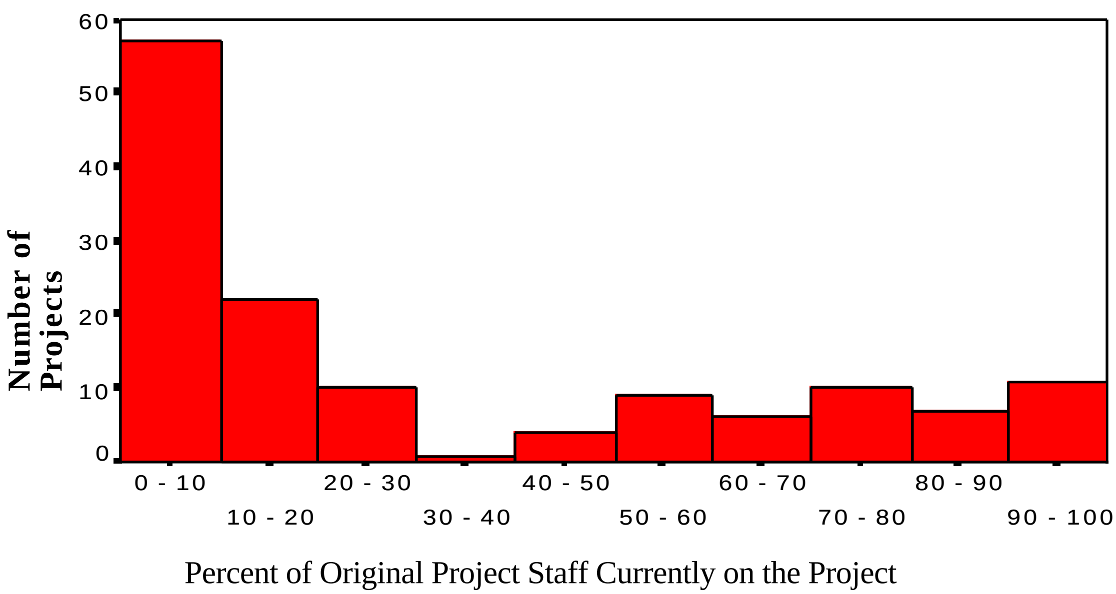


Figure 10-15: Percent of Original Staff on a Project (Program Office Survey; Number of Projects = 138).

D. Contractors' Incentives to Reduce Schedule

The Program Office and contractor surveys asked questions to determine contractors' incentives to meet or shorten a project's schedule. The Program Office survey asked project managers to indicate the schedule-related incentives they provide to contractors through their contracts. The contractor survey asked contractors to indicate the incentives from Program Offices, and their overall incentives to meet or exceed project objectives based on their companies' bottom line. The results indicate that contractors have few incentives to shorten project schedules.

D.1. Program Office Incentives for Contractors

The Program Office survey asked questions about schedule-related incentives the Program Office provided to contractors for on-time or early completion of a project or major milestone. The vast majority of project managers report no financial incentives for contractors to either meet or reduce the project schedule. Two-thirds of all projects include no financial incentives for on-time completion. Some 75 percent of project managers report that their contracts provide no financial incentive for early completion, while 85 percent report that the incentive for early completion was less than 2 percent of the contract value. The average incentive for *on-time* completion across all projects is less than 3 percent of the contract value. The average incentive available for *early* completion of a project or major milestone is less than 1.5 percent of the contract value.

Despite the low schedule-related incentives reported, these numbers may significantly overestimate the schedule-based incentives. Written comments and follow-up interviews revealed that many respondents included the entire potential award fee in their responses, and not the percentage of the award fee associated solely with schedule performance. The award fee is typically based on a number of factors, including schedule. A contractor may receive all or nearly all of the incentive because of considerations other than schedule. This would imply that the amount of incentive specifically available for on-schedule performance or shortened schedule may be even less than these small averages indicate. The average percentage of available award fees given to contractors is near 93 percent.[101]

[101] Based on conversations with Mr. Blaise Durante, Deputy Assistant Secretary of the Air Force (Acquisition) Management Policy and Program Integration (SAF/AQX).

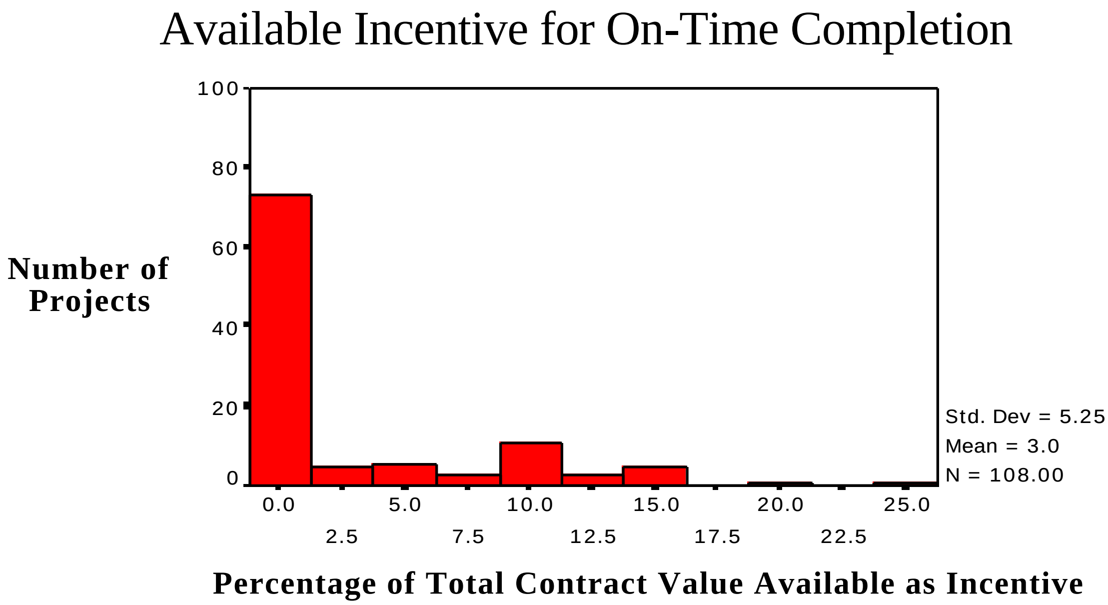


Figure 10-16: Percentage of Contract Value Available for Incentive for On-Time Completion of the Project or a Major Milestone. (Program Office Survey; Number of Projects = 108).

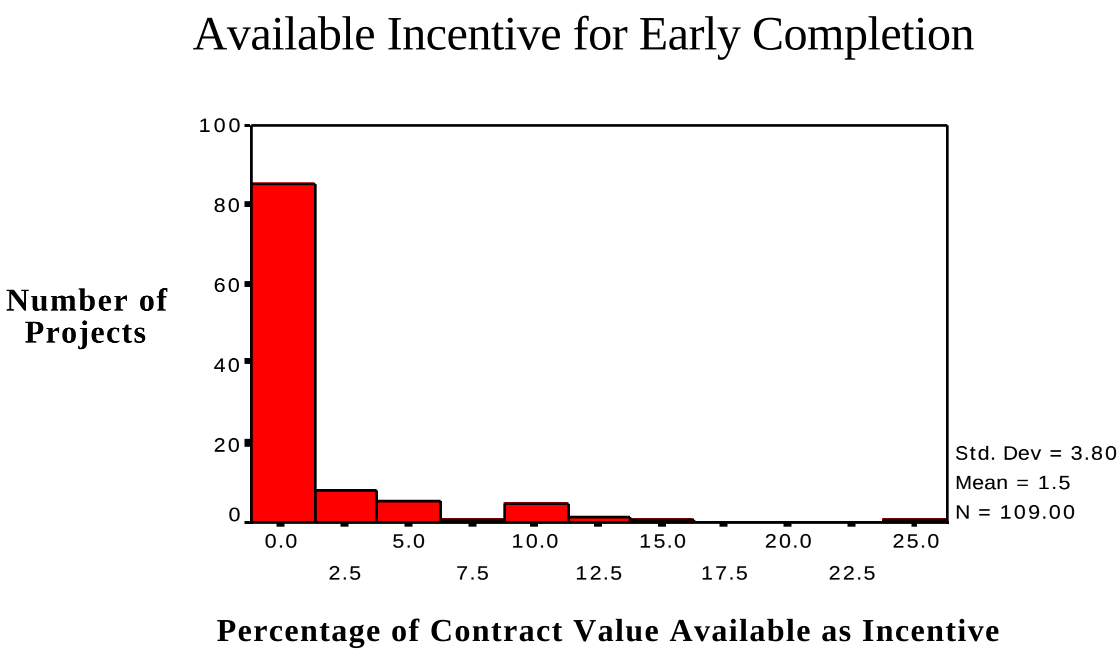


Figure 10-17: Percentage of Contract Value Available for Early Completion of a Project or Major Milestone (Program Office Survey; Number of Projects =108).

Comments from several industry representatives involved in the Lean Aerospace Initiative indicate that award fees may play a significantly larger role than indicated by financial aspects. The percentage award fee is in essence a report card from the Program Office on the company's response to the Program Office's desires and concerns. Senior managers at the company use the percentage of the award fee to indicate the project's status.

Another issue is that contract incentives for on-time completion are based on the schedule as it exists at the time of evaluation or completion, not the original contracted schedule. The contracted schedule can and often does change by mutual agreement. This allows contractors to be "on schedule" despite the fact that the schedule has lengthened significantly.

The observation that there is not a significant incentive schedule fulfillment and reduction is consistent with the low reported priority placed on those ends by the Program Offices.

D.2. Program Office Incentives as Viewed by Contractors

The contractor survey asked respondents to rate the extent that a Program Office provides specific financial or other incentives to reduce total project cost, cut unit cost, shorten schedule, enhance technical performance, and increase reliability and ease of maintenance. A large majority of respondents reported that the Program Offices provide no incentive for exceeding any program objectives. Most incentives appear to be based on meeting the stated project goals and not exceeding them. Incentives to reduce total program cost were rated higher than reducing unit cost, exceeding performance requirements, or shortening schedule—all of which were statistically equivalent. Incentives to exceed operational and maintenance requirements were rated below the others. When viewed across all projects, none of the incentives were rated as greater than small, with a large majority of projects carrying no customer-provided incentives to exceed project goals.

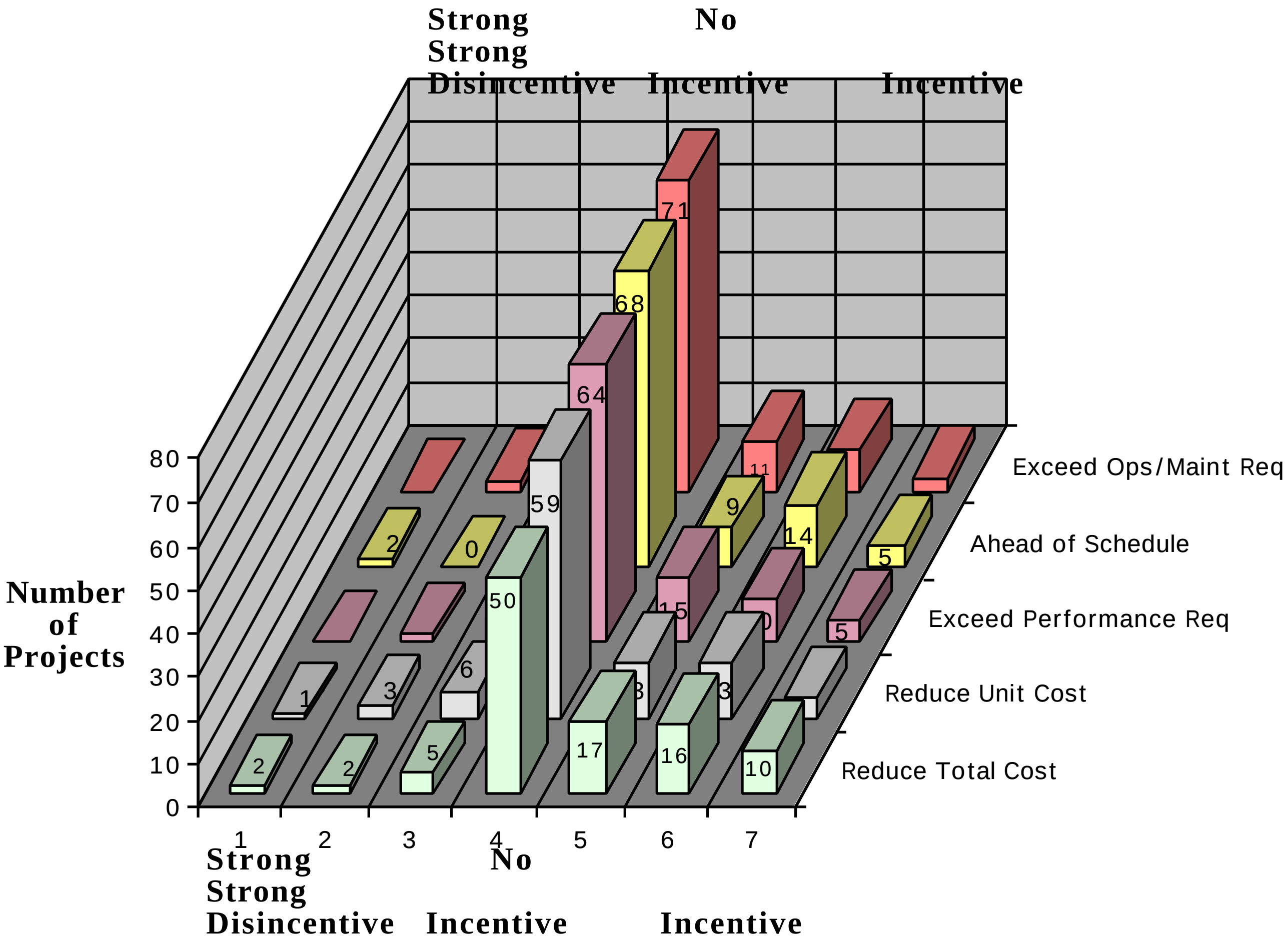


Figure 10-18: Program Office Incentives for Exceeding Project Goals as Viewed by Contactors (Number of Projects = 102).

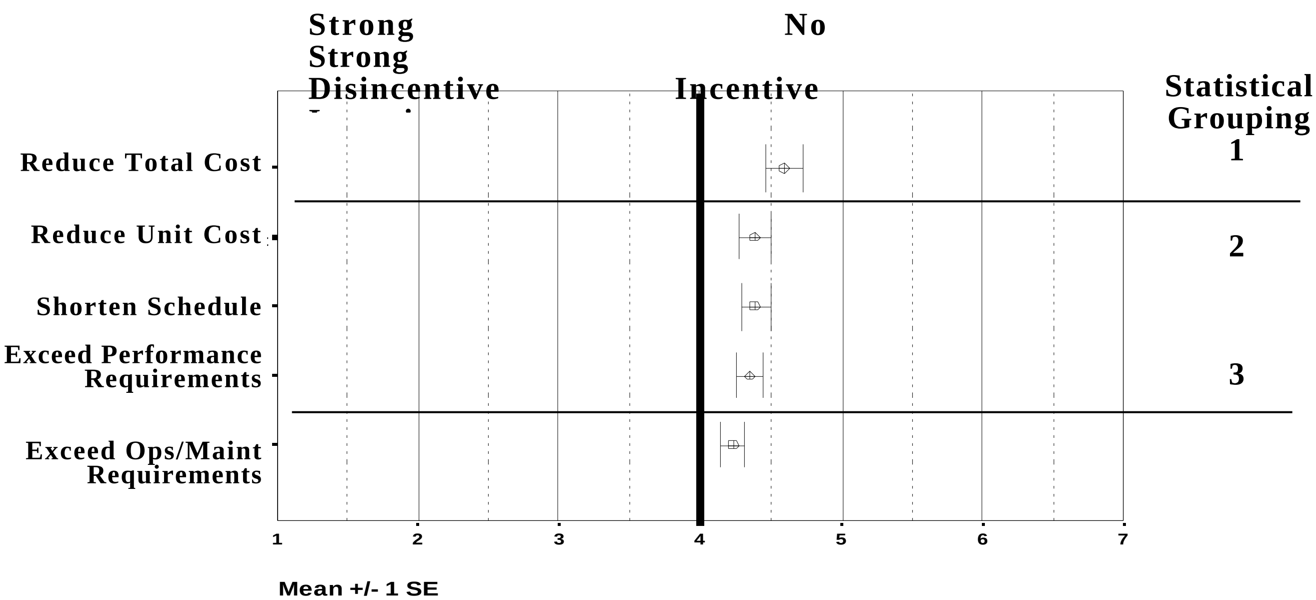


Figure 10-19: Average Contractor Incentives Provided by Program Office for Exceeding Project Goals (Contractor Survey; Number of Projects = 102).

Some 73 percent of contractor project managers indicated that the Program Office did not provide any incentives, or in some cases provided negative incentives, to shorten schedule. Only 18 percent indicated that the customer provided more than a slight incentive to shorten project schedules. These findings are consistent with the responses to the Program Office survey indicating that a vast majority of Program Offices do not provide any schedule-related incentives.

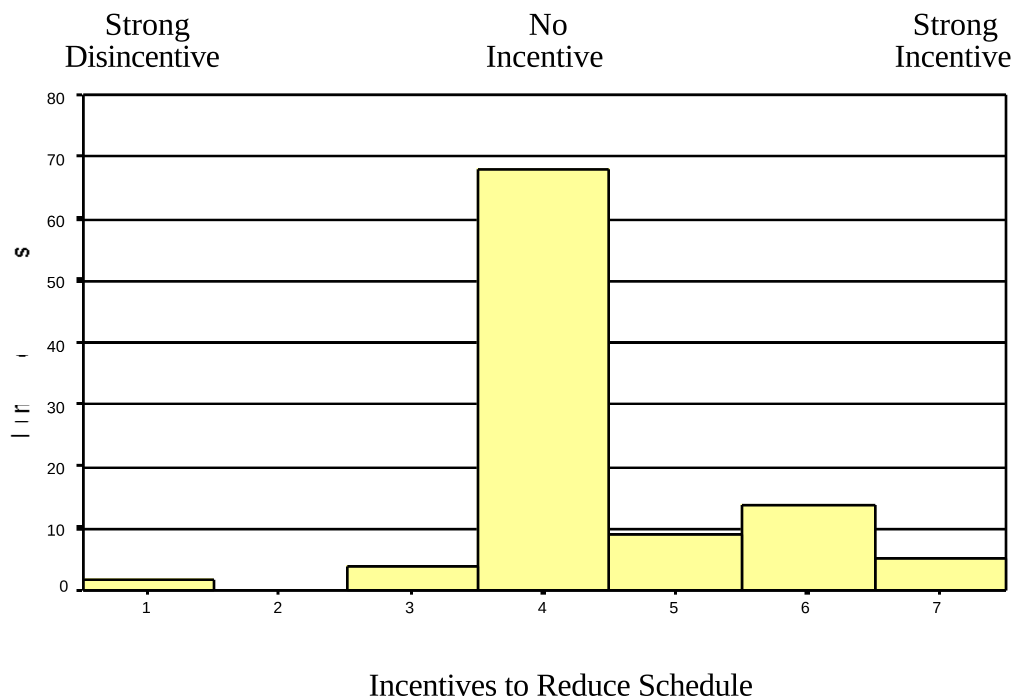


Figure 10-20: Contractor Perceived Incentives for Reducing Schedule -- Distribution of Responses from Contractors on the Incentives Provided by the Program Office (Contractor Survey; Number of Projects = 102).

The type of contract (cost-plus or fixed-price) and the selection method (sole-source or competitive) did not significantly affect contractors' incentives. Most working both under fixed-price and on cost-plus contracts indicated a very small incentive to shorten project schedules. Similarly, companies working under competitive-selection and sole-source contracts report few incentives to shorten project schedules. There do not appear to be any significant customer-provided incentives to shorten project schedules even when there is direct competition to win a contract. Respondents represented roughly equal numbers of fixed-price (41) and cost-plus (46) contracts, and equal numbers of competitive (53) and sole-source (46) contracts.

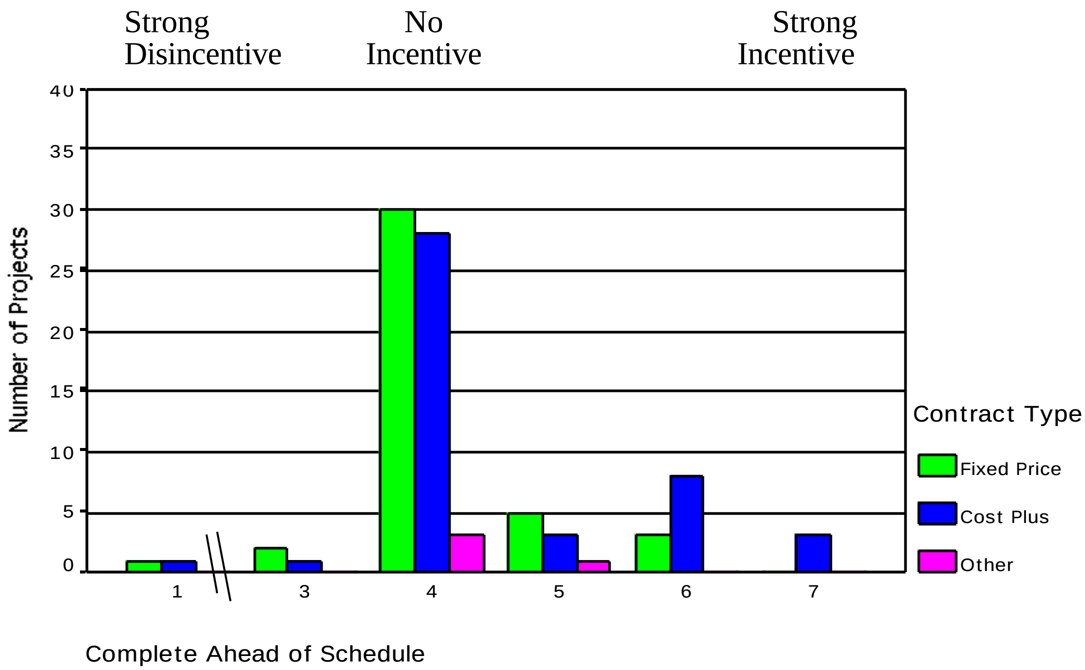


Figure 10-21: Perceived Program Office Incentives to Complete Project Ahead of Schedule for Fixed-Price and Cost-Plus Contracts (Contractor Survey; Number of Projects = 91).

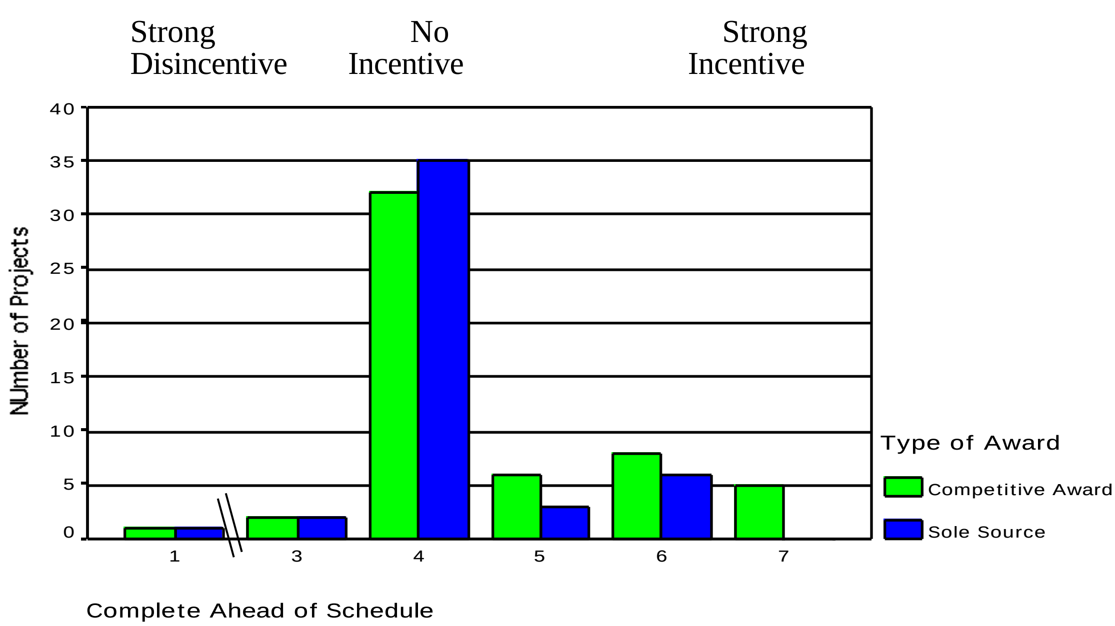


Figure 10-22: Level of Customer-Provided Incentives to Complete Projects Ahead of Schedule for Competitive and Sole-Source Contracts (Contractor Survey; Number of Projects = 99).

D.3. Contractor's Bottom-Line Incentives

To measure a company's overall or total incentive associated with a project, the Contractor survey asked project managers to indicate the bottom-line impact or net financial impact of exceeding various project goals on their company. Such impacts may include follow-on business and factors such as increased company stature. These incentives were reported to be significantly higher than those provided by the Program Office. The objectives with the highest incentives were reducing total program cost and reducing unit costs. Shortening schedule was rated significantly lower than cost but above exceeding performance and reliability requirements. The goals of exceeding performance and maintenance requirements were statistically equivalent and rated significantly lower than other objectives. A large percentage of respondents indicated that they had no net or overall incentive to exceed performance or maintenance requirements.

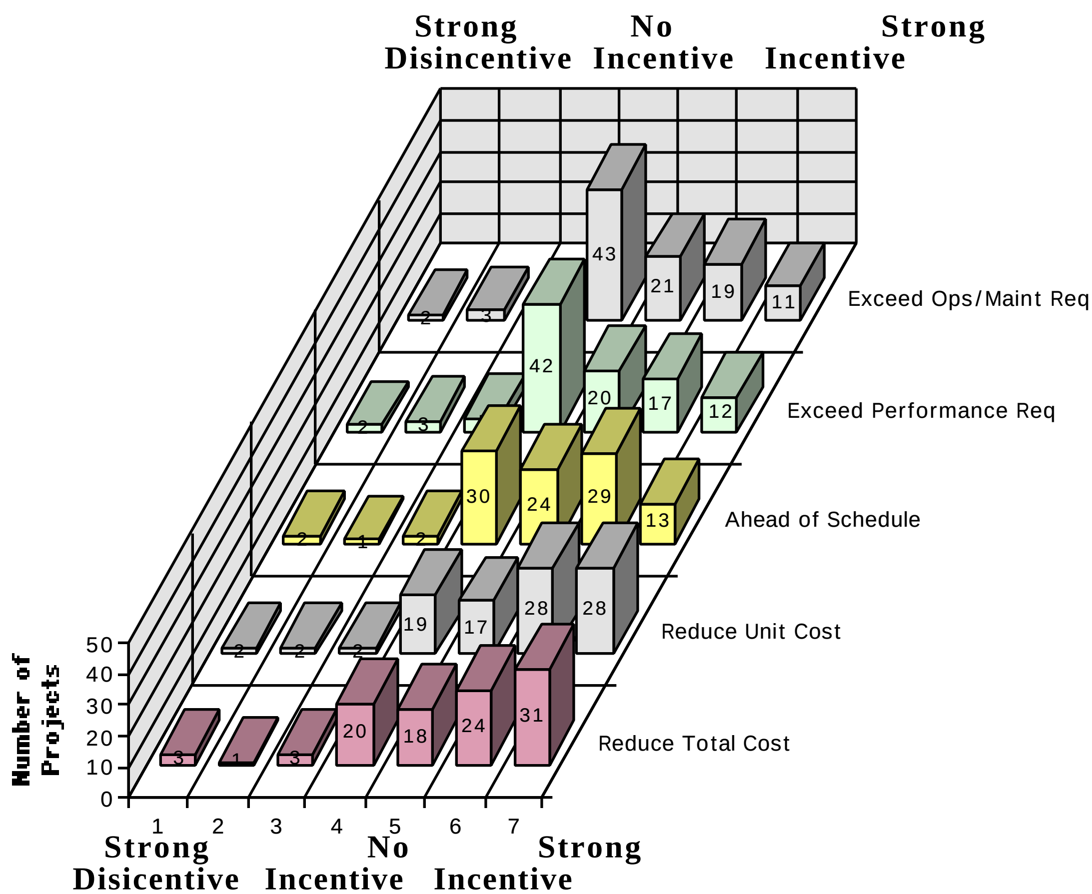


Figure 10-23: Contractors' Total "Bottom-Line" Incentives for Exceeding Various Project Goals (Contractors Survey; Number of Projects = 101).

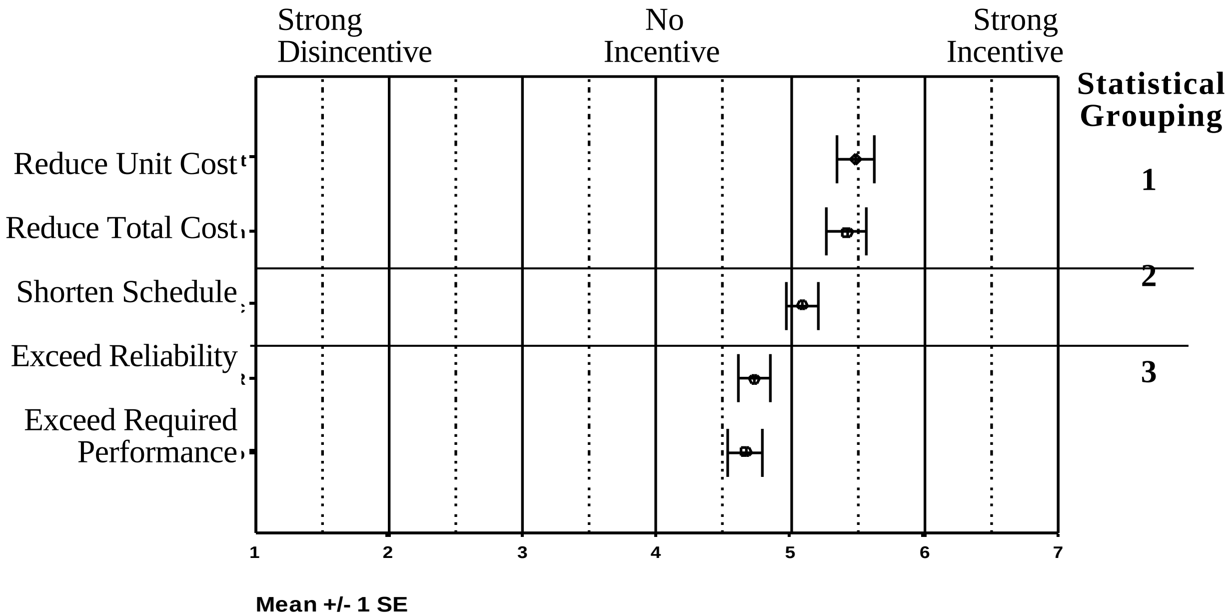


Figure 10-24: Average "Bottom-Line" Incentives to Exceed Project Objectives (Contractor Survey; Number of Projects = 101).

When looking specifically at schedule-related incentives, 59 percent of contractors report little or no incentive to reduce schedule; 41 percent indicate that they do feel some form of overall incentive to reduce schedule. During follow-up interviews, several project managers indicated that reducing schedule is seen as integral to reducing cost. This is consistent with the results of analysis of the reported incentive by the contract type, either cost-plus or fixed-price.

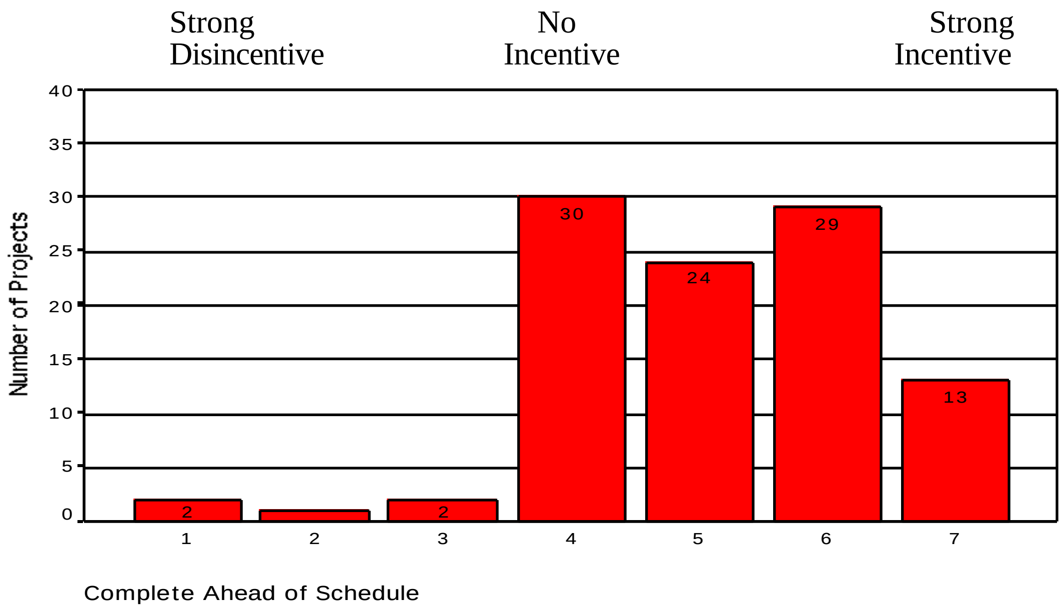


Figure 10-25: Distribution of Responses for Bottom-Line Impact of Completing Ahead of Schedule (Contractor Survey; Number of Projects = 101).

The type of contract between Program Office and contractor played a significant role in determining contractors' total incentive to exceed project objectives. Companies with fixed-price contracts account for a disproportionate share of those reporting incentives to reduce total program cost, reduce unit cost, and shorten schedule. Companies with fixed-price contracts reported significantly higher net incentives to exceed cost goals than those with cost-plus contracts. Companies with cost-plus contracts report only a slight net incentive to reduce costs or shorten schedule. Most companies with cost-plus contracts report Program Office incentives and bottom-line incentives as equal, indicating that these companies have little internal incentive to exceed project goals. Companies working on projects with fixed-price contracts reported a slightly higher incentive to reduce schedule than those with cost-plus contracts. Both companies with cost-plus contracts and those with fixed-price contracts reported few incentives to exceed performance and reliability goals.

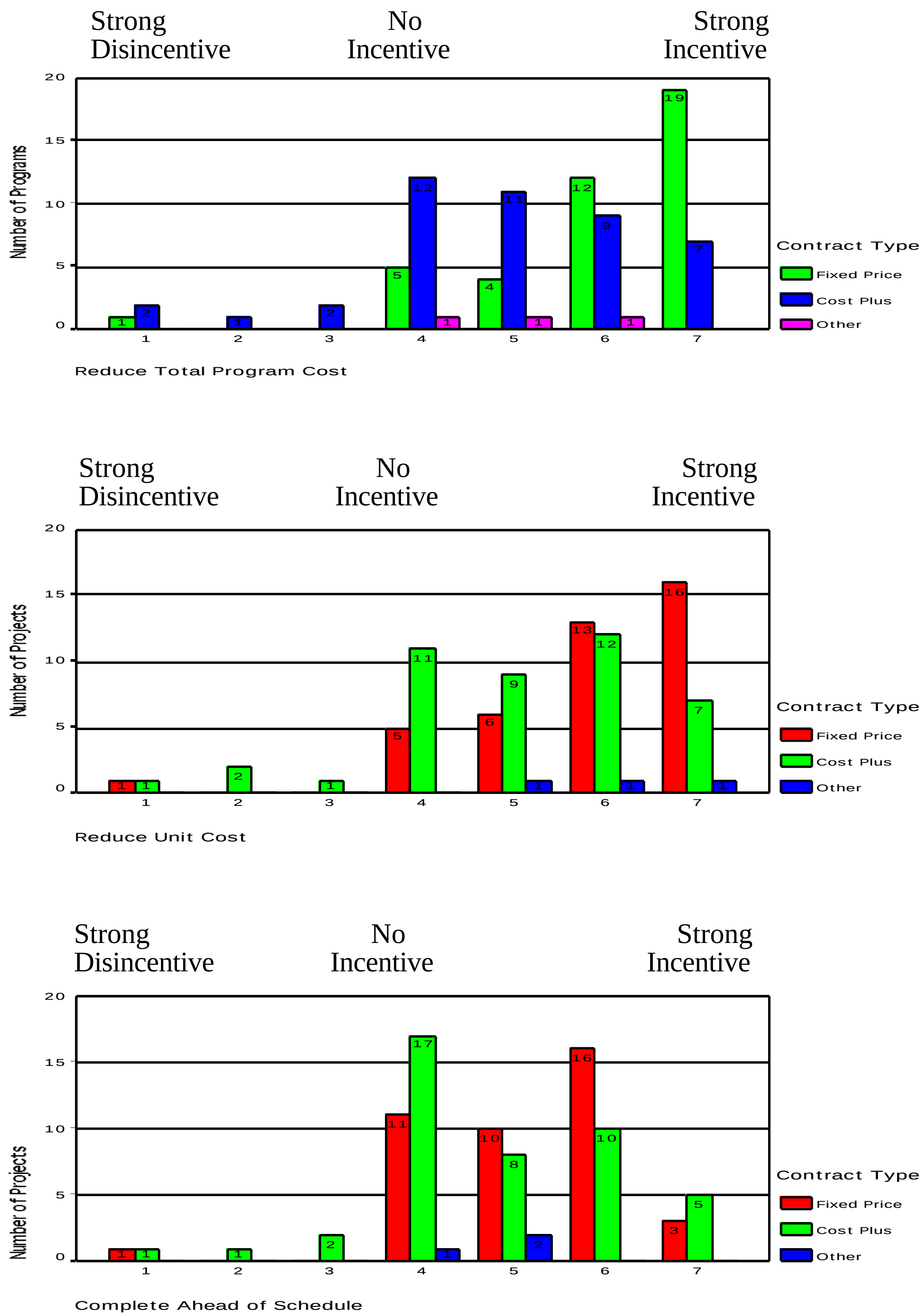


Figure 10-26: Contractors' Reported Bottom-Line Incentives to Exceed Project Cost and Schedule Goals by Project Type (Number of Projects = 101).

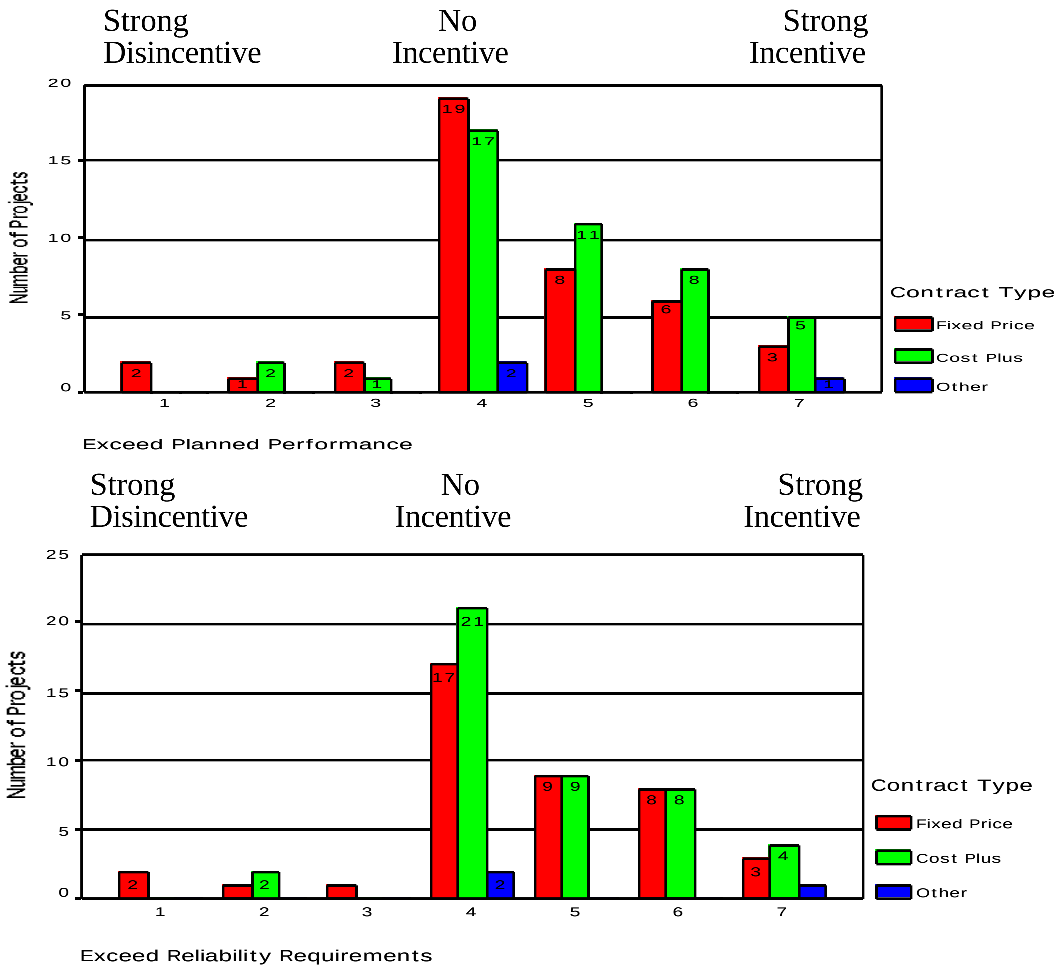


Figure 10-27: Contractors' Reported Bottom-Line Incentives to Exceed Project Performance and Requirement Goals by Contract Type (Number of Projects = 101).

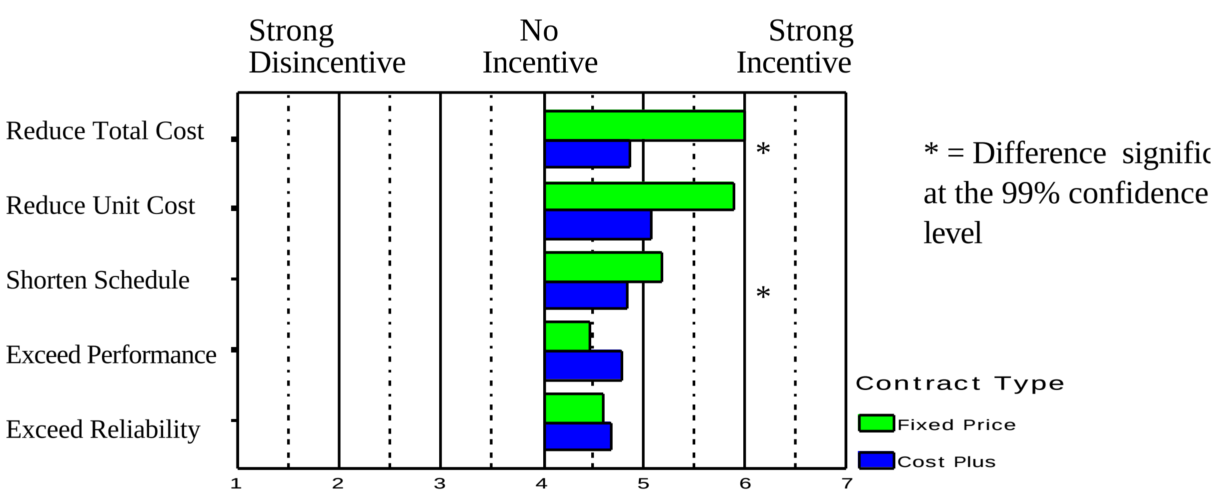


Figure 10-28: Average of Contractor Reported Net or Bottom-Line Incentives by Fixed-Price and Cost-Plus Contract Type (Number of Projects = 101)

Summary of Schedule-Related Incentives

Pentagon respondents report that users have significant incentives to exceed program cost, schedule, performance, and reliability goals. Users incentive to reduce project schedules is rated slightly higher than users' incentives to reduce cost or increase performance. Overall 80 percent of projects are reportedly desired as soon as possible, and 73 percent are reportedly needed to meet current operational requirements.

Analysis of Pentagon responses indicates few incentives at the Pentagon level for reducing the schedule in the majority of development projects. The principal Pentagon actors on individual development efforts—the program element monitors and the Air Staff action officers—do not see shortening cycle time as either an important project or personal objective. They rate shortening schedules as the fourth of four project objectives, and indicate that shortening schedules has little impact on their performance rating or potential for promotion. Higher-level Pentagon actors, such as mission area directors, oversee many development efforts, and the outcome of a single project has less of an impact on their careers.

As shown, few incentives within a Program Office aim to shorten a project's schedule. Incentives for project managers are to meet the project schedule and not to shorten it. The Program Offices report shorter schedules most often as the fourth of four objectives, and do not rate short schedules as particularly important on their own. Shortening the project schedule is not seen as having a significant impact on a program manager's performance rating or career, and there is apparently little personal accountability for project performance. Given the multiplicity of project managers per project, it is difficult to assign either credit or blame to a project manager based on a project's performance. Across most projects there appears to be little incentive to reduce project schedules within the Program Offices.

The Program Offices also provide few incentives for contractors to exceed project objectives. Meeting the objectives--not beating them--appears to be the overall goal in a majority of projects. Program Offices report providing practically no contract-based incentives for either on-time or early completion of a major milestone or a project. Incentives perceived by contractors focus on cost and depend largely on the type of contract. Projects with fixed-price contracts account for a large portion of reported net incentives to reduce cost by reducing schedule. Projects on cost-plus contracts report little Program Office or overall incentive to exceed project goals.

The lack of personal and organizational incentives for defense contractors, Program Offices, and the Pentagon indicates that the goal is to meet project objectives, not to exceed them. There is little perceived incentive to exceed a project's objectives at any level. Reducing schedules is most often the last of project objectives. Additional efforts and resources, if available, would likely be placed on the higher-rated objectives of reducing cost or improving performance, not on reducing project schedules. The effects of the low priority accorded to shortening development schedules, and the lack of incentives for doing so, can be seen in the schedules' execution.

The original schedule is based not on a project's development requirements but on expected funding limitations. In the contracting phase, the original DoD project schedule is the central factor in determining the contract schedule; contractors have no incentive to bid anything other than what the government expects. Nor is there any mechanism to rectify the influence of the original project schedule on development To reduce development times, DoD must improve, redesign, or dramatically alter the process used to develop project schedules.

The impact of the project scheduling processes and the lack of schedule-related incentives can be seen in the results of the projects surveyed. The impacts include few accelerated projects, many delayed projects, project instability, and higher costs. These impacts are addressed in the next chapter.

Chapter 11

Executing Project Schedules during the Development Phase

Although the contracted schedule plays a significant role in product development times, those times can grow or shrink depending on technical problems, funding constraints, and changing Air Force objectives. The execution of a project's development schedule also depends on the appropriateness of the schedule, the contractor's execution, and responses of the Program Office and the contractor to unforeseen events. The responses to unforeseen events, in turn, depend on the schedule-related incentives experienced by various organizations.

This chapter looks at the execution of project schedule during development. First, it investigates differences among the planned time, the achieved schedule, and the estimated time required to develop the projects based on their technical requirements. It then looks at the causes of deviations from project plans, and the tradeoffs made in response to changes in the plan. It identifies how often and to what extent these changes occur. This chapter also identifies the primary barriers to shortening project schedules.

A. Achieved Project Schedules in the Development Phase

The extent to which projects achieve their planned schedule is one measure of the effectiveness of the schedule development process. Another measure is time planned versus the time posited to be required to perform the development-related activities. Technical barriers would indicate that the schedule development process underestimated the necessary time. Large differences between the project schedule and the estimated time needed to fulfill the requirements would indicate significant slack in project schedules and longer-than-necessary development times.

A.1. Achieved versus Planned Project Schedules

To compare achieved times with planned project schedules, the three surveys asked respondents how much their project had changed from its initial schedule. The amount of schedule change was based on delivery of the first production item or other appropriate milestone versus the initial project plan. The surveys also asked respondents to provide the dates of key milestones for both the initial and the current schedule.

The responses indicated a large number of project slips. The average project slip measured across all projects surveyed was 12.1 months. This might indicate that planned schedules may be too short to allow for required development activities. The average schedule slip, however, is misleading, as a significant fraction of projects do not slip. Among those that do slip, most schedule changes are reportedly due to external factors and not to technical problems. The surveys indicate that 106 of 271 projects--or 39 percent--are within 3 months of their initial schedule. Some 77 projects, or 28 percent, are reportedly between 3 months and 1 year of their initial schedule. Only 57 of the 271 projects, or 27 percent, are reportedly more than 1 year behind their initial schedule.

The survey results also show that despite the large number of development projects that are exactly on schedule, few are ever completed early. Of the 271 projects, only 14--or 5.2 percent--were reportedly ahead of their initial schedule by 3 months or more.

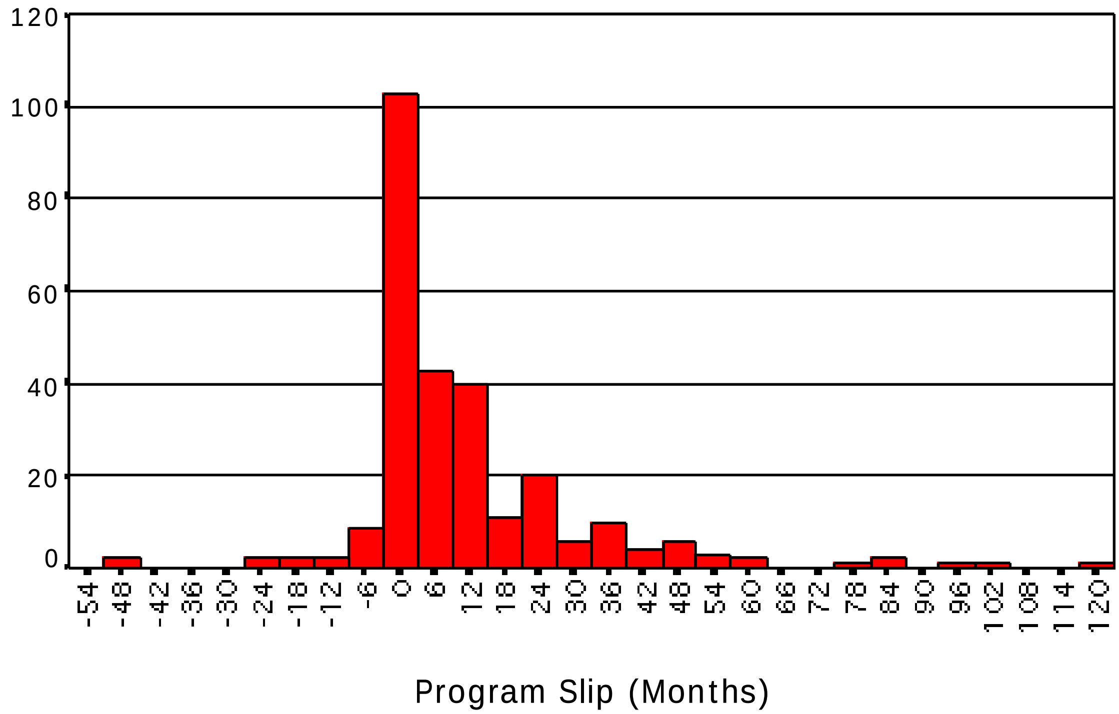


Figure 11-1: Project Schedule Performance Based on Initial Project Plan (Pentagon, Program Office, and Contractor Surveys; Number of Projects = 271).

Differences in project duration do not account for the amount of project slip. The average annual slip for the 225 projects whose managers provided the necessary information is 2.71 months. This indicates that in each year of development, the average project makes only slightly more than 9 months of progress toward completion. A few projects--13, or 5.8 percent--reportedly had annual schedule slips of 12 or more months. This indicates that those projects are getting further from first production delivery every year. A project's large average annual slip may result from significant slip early in its development. Calculated annual project slips are shown in Figure 11-2.

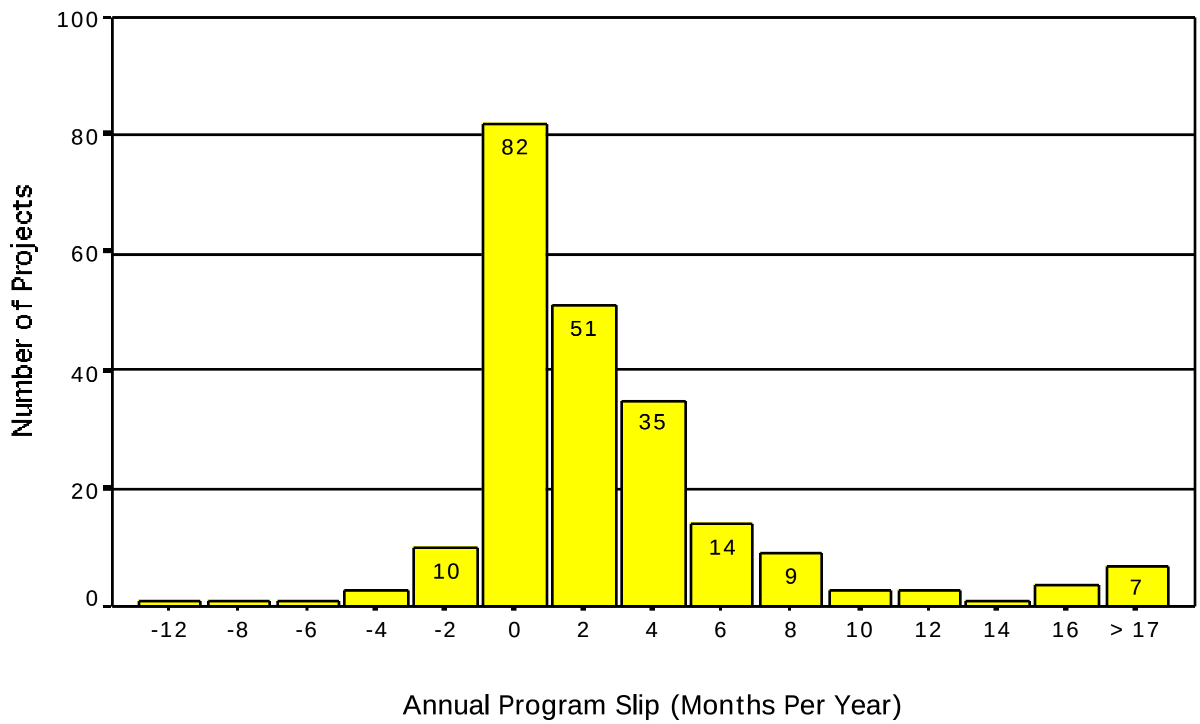


Figure 11-2: Annualized Project Schedule Performance Based on Initial Project Plan (Pentagon, Program Office, and Contractor Surveys; Number of Projects = 225).

As Figures 11-1 and 11-2 indicate, a large number of projects are exactly on schedule. There are many possible reasons for this record. Despite the clear wording of the questionnaires, respondents may have compared their project's performance to the current schedule--which had already been modified from the initial schedule. Another reason may be that project managers often do not admit to slips until the final stages, when they realize that they cannot recover from earlier shortcomings. However, respondents' answers to other questions provided support for the results as presented. The slip for projects calculated from the initial and current schedules is similar to respondents' estimates of the amount of slip from the initial plan.

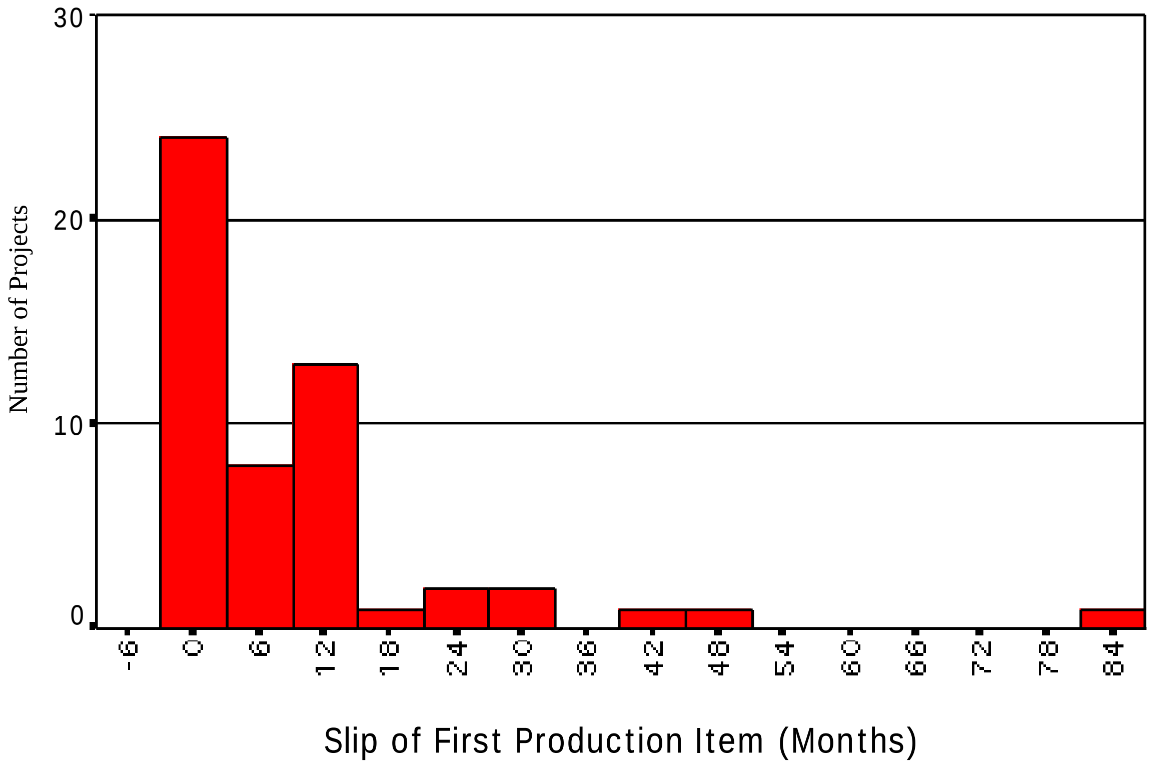


Figure 11-3: Slip of First Production Item as Calculated from Calendar Dates Provided for Initial and Current Project Plans (Program Office Survey; Number of Projects = 52).

Similar results appear in databases from other sources. The RAND Corporation collected information on all major defense acquisition projects since 1960 as reported in selected acquisition reports to Congress. Of those, some 100 projects included the information needed to calculate the amount of slip from project initiation to first production item or operational delivery. The slip per project--and the distribution of slip across many projects--is equivalent to those found in the three surveys.

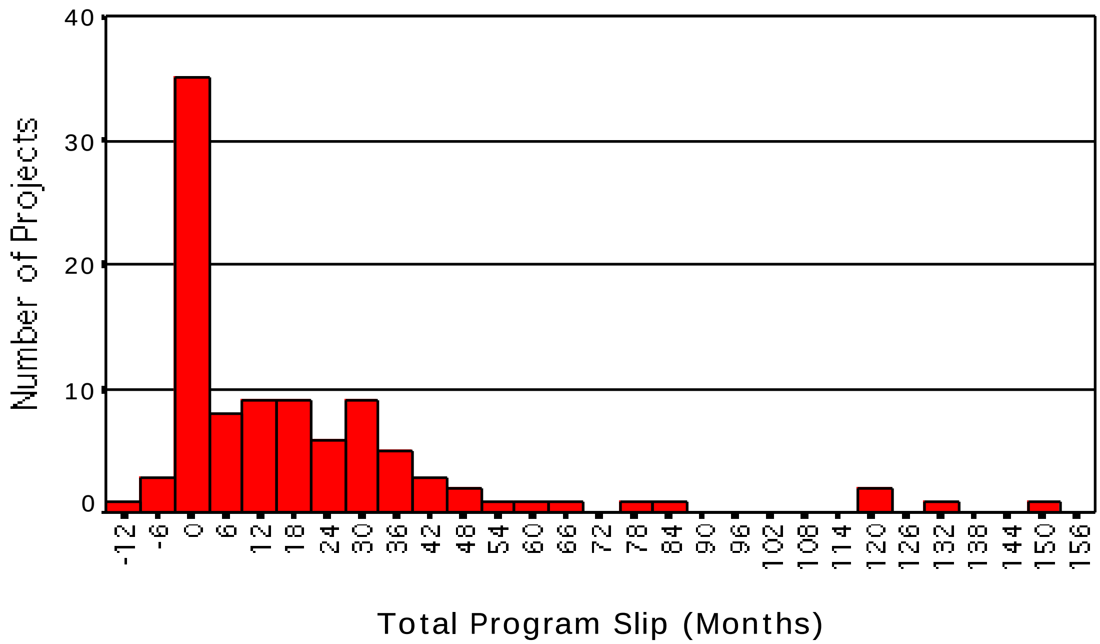


Figure 11-4: Total Slip (from Project Initiation to First Operational Delivery) for Major Defense Acquisition Projects, Based on the RAND Selected Acquisition Report Database.[102]

A.2. Causes of Project Schedule Slip

The simple number of projects that slip, and the amount of schedule slip, do not provide a complete picture of the ability of a project to meet its initial schedule. Completing the picture requires examining the causes of schedule slips. To determine what is causing schedule slips, the three surveys asked respondents to estimate the percentage of any slip stemming from funding instability, requirement changes, technical problems, or other factors. The impact of these factors can be seen in the magnitude of their effect across projects, and in the number of projects they affect.

The average amount of slip for projects at least 1 year into development was 12.1 months. Respondents attributed 5.2 of those months to funding instability, 3.1 months to technical problems, 2.6 months to requirement changes, and 1.2 months to "other causes." The average schedule slip attributed to funding instability across all programs indicates that it is the primary cause.

[102] Jarvaise, Drezner, and Norton. "The Defense System Cost Performance Database: Cost Growth Analysis Using Selected Acquisition Reports." MR-625-OSD Santa Monica, CA: The RAND Corporation. 1996.

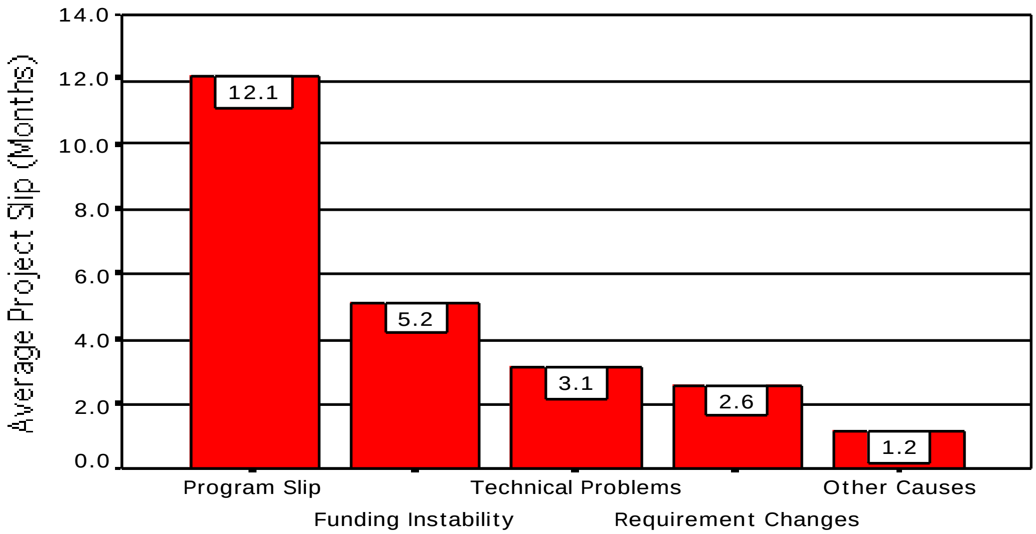


Figure 11-5: Average Slip for Projects at Least 1 Year into the Development Phase, and the Portions Attributed to Different Causes (Pentagon, Program Office, and Contractor Surveys; Number of Projects = 271).

Analyzing the data on an annualized basis yields similar results. Across all projects in development for at least one year, the average project slip was 2.1 months per year. Of those months, 1.0 per year was attributed by respondents to funding instability, 0.5 per year to technical problems, 0.4 per year to requirement changes, and 0.2 months per year to other causes.

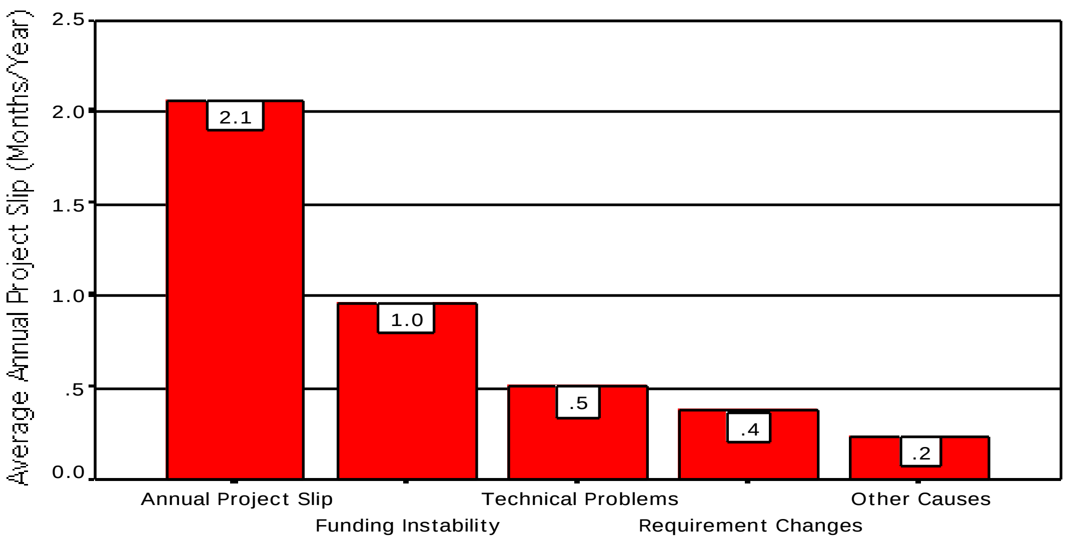


Figure 11-6: Average Annual Slip for Projects at Least 1 Year into the Development Phase, and the Portions Attributed to Different Causes (Pentagon, Program Office, and Contractor Surveys; Number of Projects = 175).

Respondents reported that technical problems account for only 25 percent of the observed slip. Factors not related to technical requirements, including funding stability, requirement changes, and "other causes," account for 75 percent of the total amount of slip. These results are also observed when slip is viewed on an annualized basis. Of course, unlike technical factors, funding instability, requirement changes, and "other causes" are typically outside the control of Program Offices and contractors.

In number of projects, 84 of 271 reported no schedule slip, and 120 reported less than 3 months' slip. Some 107 attributed some portion of their schedule delay to technical problems, 97 attributed some delay to funding instability, 89 attributed some delay to requirement changes, and 65 projects attributed some delay to "other factors." Of projects attributing slip primarily (at least 50 percent) to a single cause, 62 pointed to funding instability, 54 reported technical problems, 35 projects pointed to requirements changes, and 33 projects reported other factors.[103] Thirty-five projects reported funding instability as solely responsible for the schedule slip, and 20 projects reported technical problems as solely responsible. For 130 of 187 projects reporting any schedule slip, external factors such as funding instability, requirement changes, and other factors were the primary cause.

In terms of technical problems, the responses indicate that 105, or 39 percent, of all projects attributed some portion of schedule slip to such problems. Some 164, or 61 percent, of all projects reported no schedule delay stemming from technical problems. Of the 107 projects reporting some delays attributable to technical problems, 54 projects indicated that they were not the primary cause (accounting for less than 50 percent). Of the projects that attributed schedule delays primarily to technical problems, only 14 had delays longer than 1 year. This compares with 33 projects with over 1 year of delay that reported funding instability as the primary cause. In all, 40 of the 54 projects that reported slip primarily owing to technical problems report 12 months of delay or less. Twenty-four of those projects reported delays of 6 months or less. Overall, 198 of 271 projects--or 73 percent--attributed 25% t or less of schedule slip to technical problems.

Percent of Project Slip Attributed	Funding Instability	Technical Problems	Requirement Changes	Other
No Impact	174	164	182	206
Any Impact	97	107	89	65

103 Those projects not attributing 50% to any factor are not included and those attributing 50% for two factors are included twice.

25% or Greater	76	73	59	46
50% or Greater	62	54	35	33
75% or Greater	36	32	17	24
100% of Slip	35	17	8	21

Table 11-1: Number of Projects Attributing Schedule Slip to Funding Instability, Technical Problems, Requirement Changes, and Other Causes (Pentagon, Program Office, and Contractor Surveys; Number of Projects = 271).[104]

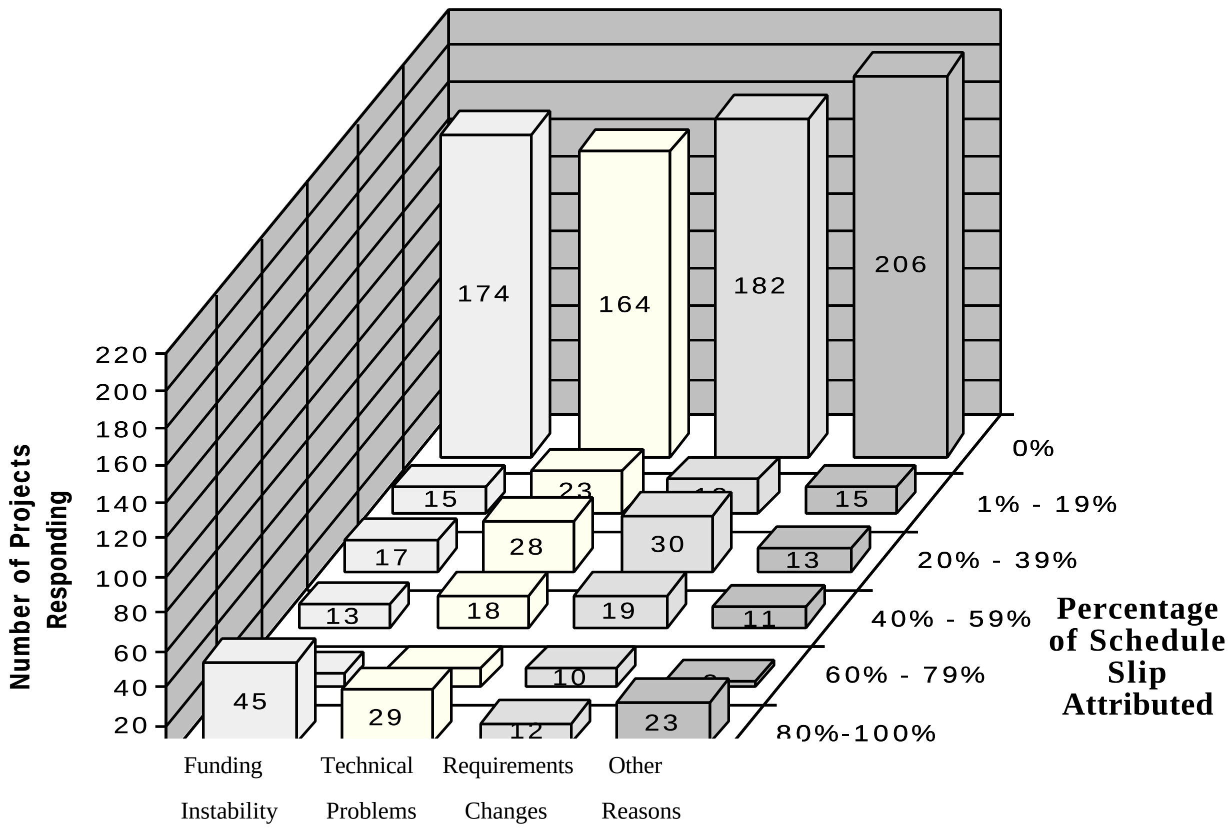


Figure 11-7: Number of Projects Attributing Percentage of Schedule Slip to Various Causes (Pentagon, Program Office, and Contractor Surveys; Number of Projects = 271).

According to the survey responses shown in Figures 11–5 and 11-6, the primary cause of project slip is funding instability, which underlies half of the total reported slip. Factors external to development requirements are causing 75 percent of all schedule delays. The fact that only 1 in 5 projects reported slip primarily (over 50 percent) stemming from technical problems indicates that many schedules are not set too short based on development requirements. This is entirely consistent with earlier findings that development-related considerations were secondary to budgetary factors in setting schedules during the planning phase.

The fact that 3 of 5 current development projects did not experience any schedule slip owing to technical problems may indicate that many managers may have been able to cut slack in their schedules without changing project requirements. This is consistent with the finding in Chapter 8 that 77 percent of all projects are funding limited, while only 23 percent are constrained by technological and engineering requirements. It may be possible to shorten development time so that technical requirements are the determining factor, without increasing technical risk or sacrificing performance. This could be done by aligning resources with actual development requirements and removing funding-based schedule limits.

This analysis indicates only the causes of schedule slip—not whether schedules are planned longer than necessary. As shown earlier, technical requirements are not the primary concern in establishing initial project schedules, nor are they contractors' primary consideration in proposing schedules. Development-related requirements are not the cause of schedule delays for a majority of projects. This would be expected if schedules were either set appropriately or were longer than necessary for the planned activities.

B. Required Versus Scheduled Development Time

It is difficult to determine the minimum time required to develop a product based on its technical requirements without a detailed understanding of the project and significant experience on similar projects. To measure the time required to develop projects based on technical requirements, the Program Office and Pentagon surveys asked respondents how long they believed it would take to deliver the first production item, given strong incentives and proper resources. While not a definitive measure of required time, the answers indicate that respondents believe projects could be completed in significantly less time than currently planned.

The Program Office survey asked project managers how long it would take to field the first system if it was deemed essential in a war. The responses were compared with the time remaining in the schedule until delivery of the first production item. Of the 37 projects with 1 year or more remaining in development, project managers estimated that the time required to field the first production item was 52 percent of the current schedule. Thus, the minimum time required to

[104] Note: Those projects not attributing 50% to any factor are not included and those attributing 50% for two factors are included twice.

develop a project is significantly shorter than most schedules. No project manager reported that the project schedule could not be shortened.

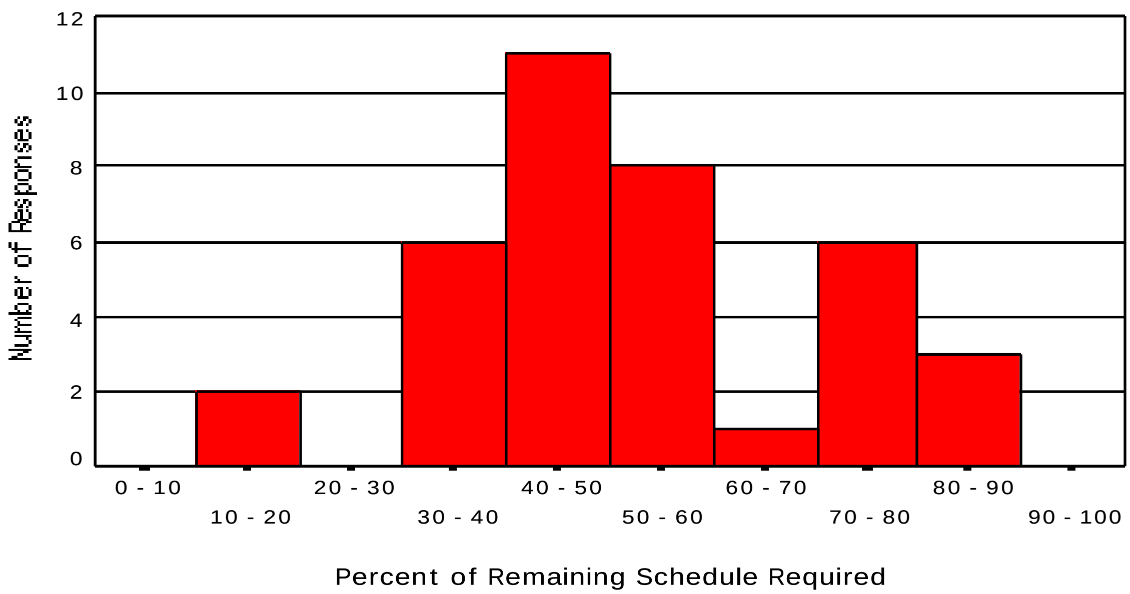


Figure 11-8: Percent of Remaining Development Schedule Required by Project Managers to Field First Production Unit in a Wartime Scenario (Program Office Survey; Number of Projects = 37).

Pentagon survey respondents were asked to provide the amount of time required from program start to first production item, assuming no funding constraints and based on the project's record to date. Twenty-six of 35 respondents thought that projects could be completed faster than scheduled. Only 6 project managers thought fielding the first production item would require the scheduled time. Three respondents indicated that significantly longer time was required than that available, indicating that a schedule slip would likely occur. These responses indicated that, in the absence of funding constraints, on average 73 percent of the current schedule was needed to complete the current set of projects.

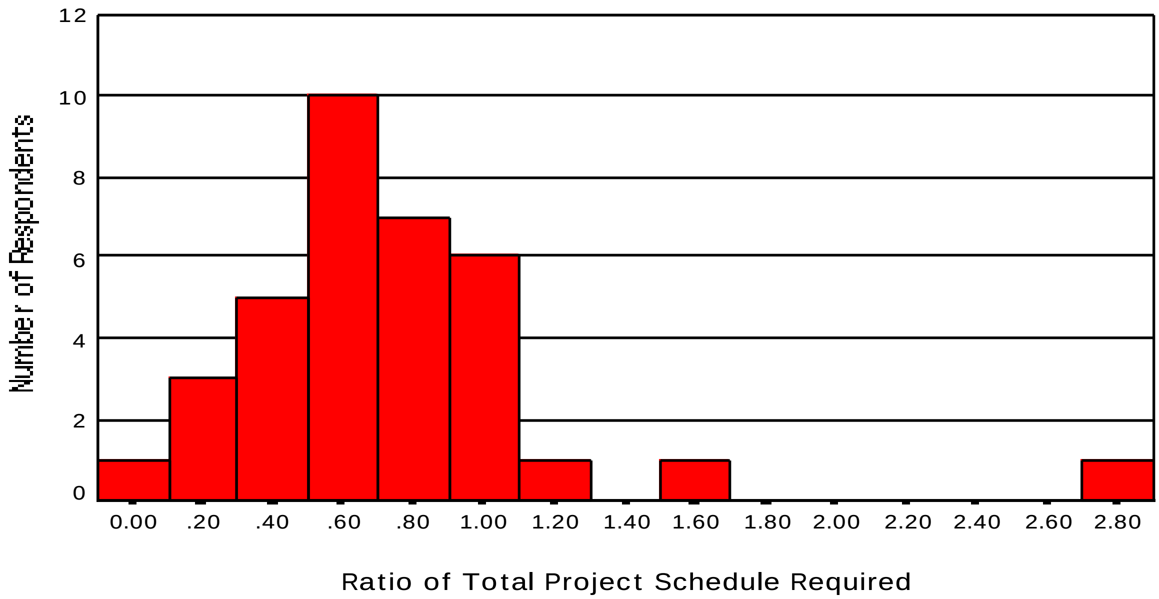


Figure 11-9: Ratio of Planned Schedule to Required Time Estimated by Pentagon Respondents, Assuming No Resource Constraints (Number of Projects = 35).

Program Office and Pentagon respondents did not base the ability to accelerate projects on a different technical approach. Thus these responses may significantly underestimate reductions in development times that are possible.

While these results do not provide firm evidence that projects could be completed faster than currently planned, they do indicate that the people most closely involved believe that it could occur without loss of technical capability. This indicates that Program Office and Pentagon respondents believe the time allowed in current schedules is significantly longer than required to accomplish the specific development tasks. The data suggest that reducing funding-based constraints and focusing on project schedules could cut development times by 25 to 50 percent—without changing the character of the projects.

Experiences in the commercial sector support the notion that a focus on cycle time can yield dramatic cuts in development times and costs, boost product quality, and help companies meet customers' needs. Many commercial firms have cut development times from 50 to 70 percent.[105]

[105] Dr. Chris Meyer. "Lessons From Industry" Lean Aerospace Initiative Plenary Session. Hartford CT. Sept 1997.

C. Causes of Changes in Project Plans

To determine the major causes of changes in plans, the Program Office and contractor surveys asked respondents to rate potential sources of project instability. The list was compiled from available literature and interviews with program managers. The surveys asked respondents to rate the impact of each factor on their project, from "not a factor" to "the primary factor." The results show that the most significant causes of program instability are changes in annual budget allocations. Rated significantly lower were unanticipated technical challenges and changes in users' requirements. Still lower were long acquisition cycles, staffing changes among contractors and Program Offices, changing service priorities, and poor contractor performance. Rated lowest were technical problems in associated projects.

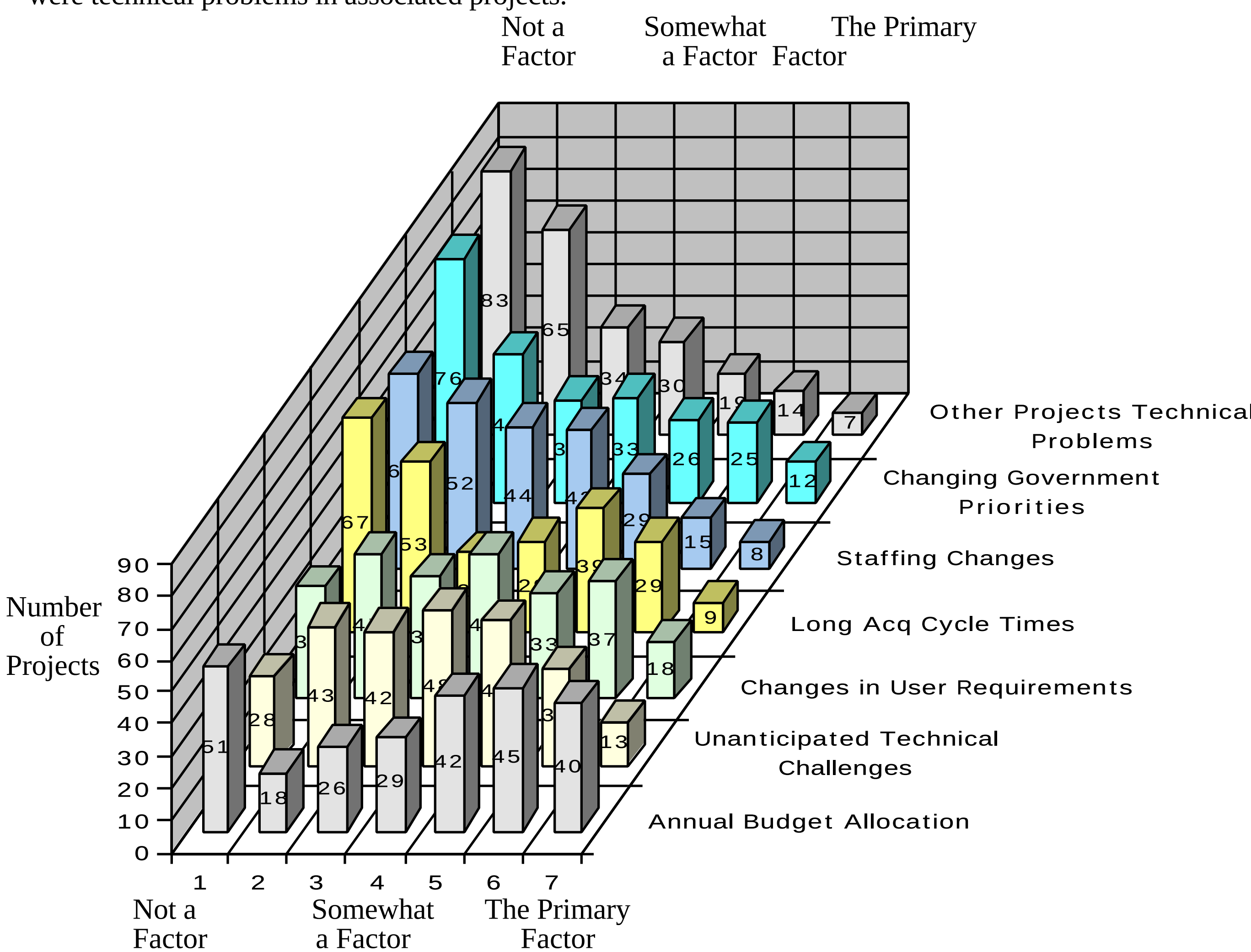


Figure 11-10: Causes of Instability in Project Planning and Execution (Program Office and Contractor Surveys; Number of Projects = 245).

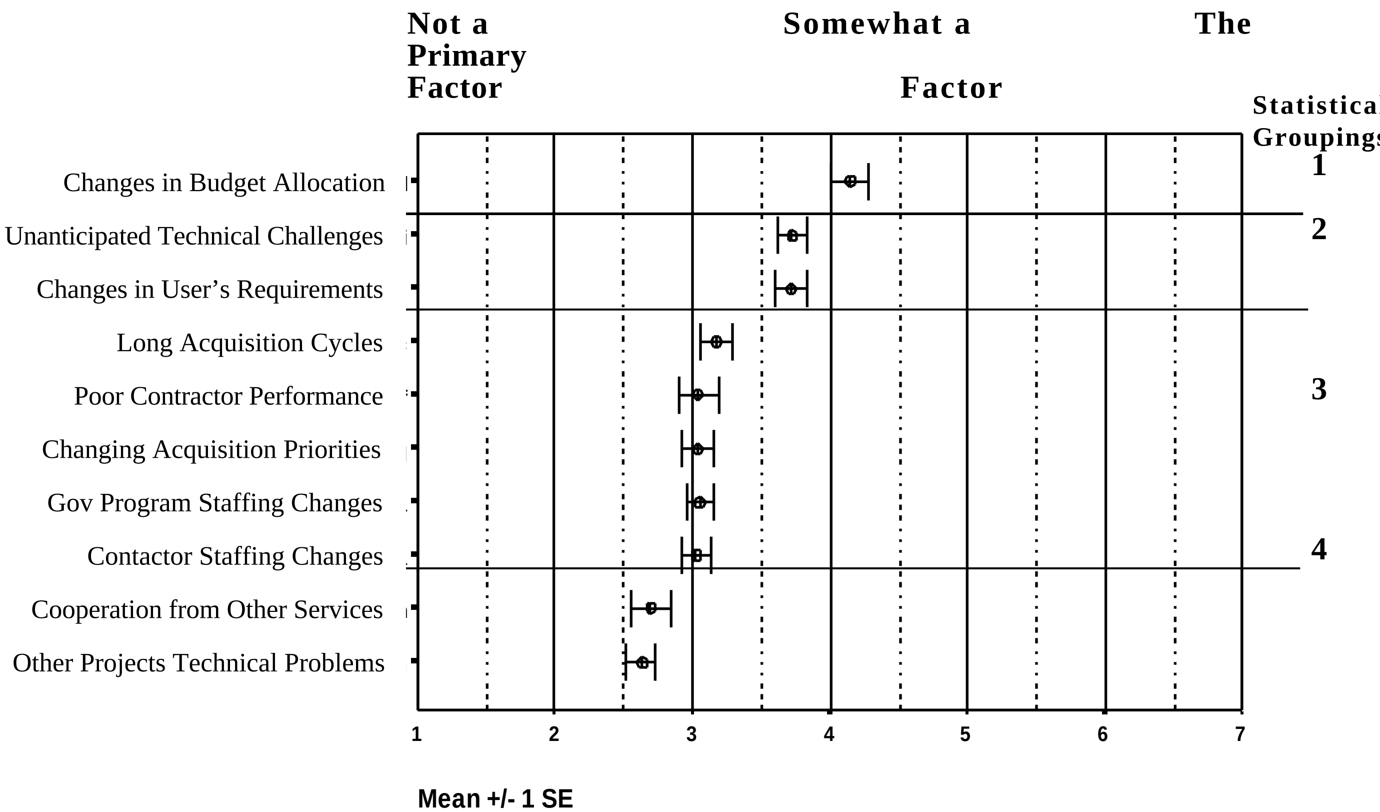


Figure 11-11: Average Responses on the Causes of Program Instability (Program Office and Contractor Surveys; Number of Projects = 245).

Of the factors affecting project instability, budget allocations were rated a larger factor than technical challenges in 124 projects, while technical challenges were rated as more important in 86 projects. Thirty-five project managers rated them the same. Changes in budget allocation had more effect than changes in user requirements in 115 projects, while changes in user requirements rated higher in 93 projects. Changes in requirements and technical challenges were rated roughly equal, with 97 project managers indicating technical problems and 90 managers indicating user requirement changes as exerting a larger effect. Sixty-one project managers rated them equal. This indicates that budget instability is the most prominent factor in project instability, but technical problems and changes in user requirements also play a significant role.

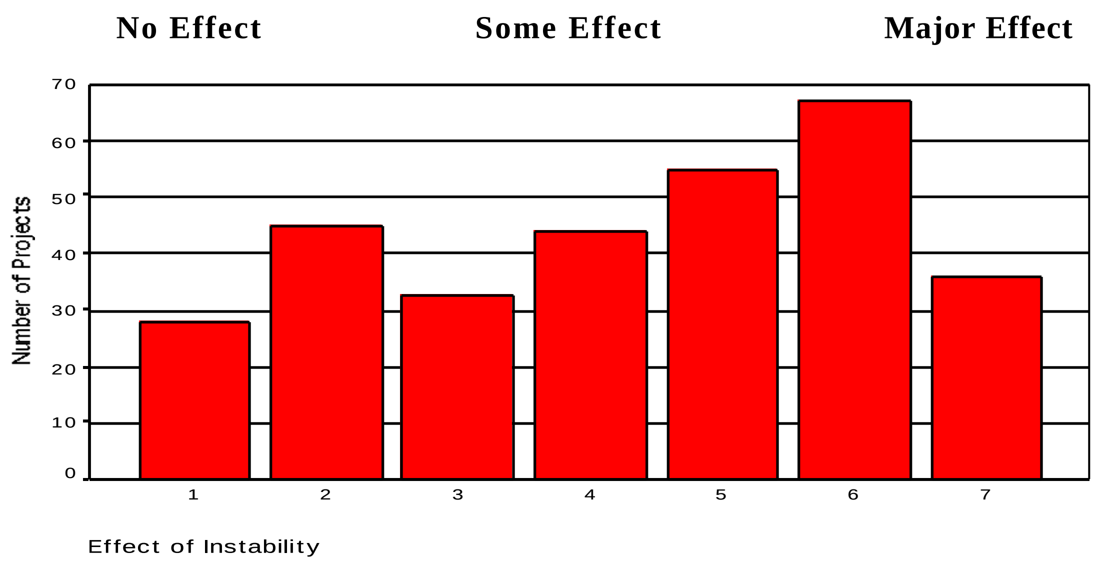


Figure 11-12: Effect of Program Instability on Ability to Meet Projects' Overall Objectives (Pentagon, Program Office, and Contractor Surveys; Number of Projects = 309).

Pentagon respondents indicated less effect from funding and technical instability than Program Office and contractor respondents. Forty percent of Pentagon respondents indicated that program instability had little effect, while 25 percent of contractors and 16 percent of government project managers indicated little effect. Thirty-five percent of both government and contractor project managers indicated that program instability had a significant or major impact on their projects ability to meet its goals, while 24 percent of Pentagon respondents indicated a similar level of impact.

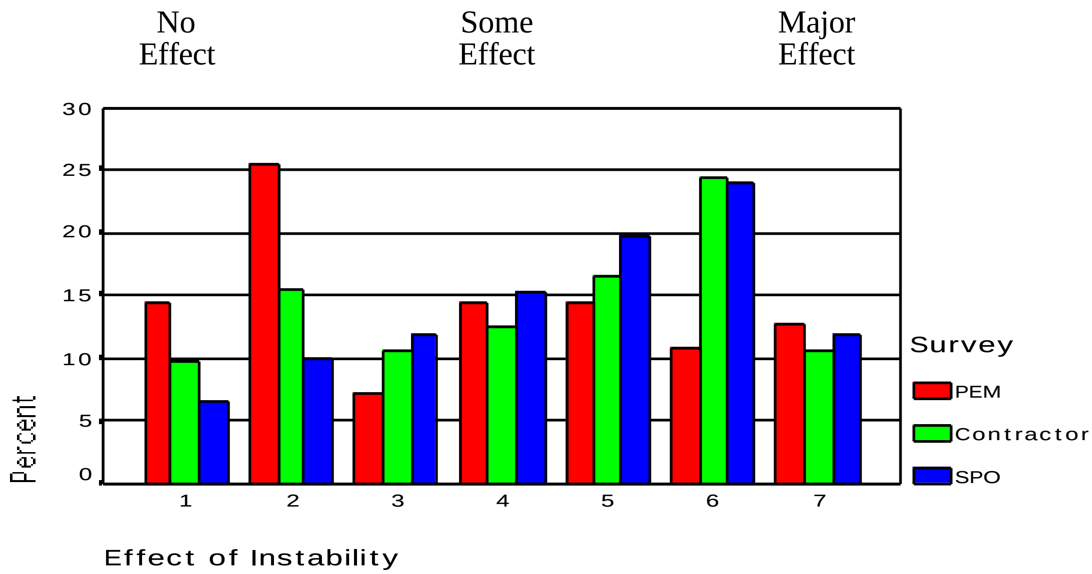


Figure 11-13: Effects of Program Instability Reported by Government Program Managers, Contractor Program Managers, and Pentagon-Level Respondents.

The contractor and Pentagon surveys asked to what extent managers could head off program instability before it occurred, and to what extent they could mitigate the effects of instability once it did occur. Neither the Program Offices nor the contractors reported much success in avoiding instability or mitigating its effects. But both groups were reportedly more successful in mitigating negative effects than avoiding instability in the first place. Few responded that they were "very successful" in avoiding or mitigating the negative effects of instability. When efforts to avoid project instability fail, managers must alter their plans, making choices and tradeoffs based on perceived objectives and incentives. [106]

[106] The research on program instability was conducted in collaboration with Dr. Eric Rebentisch of the Lean Aerospace Initiative. For more detailed information please see his report: "Managing Under and With Program Instability." Lean Aerospace Initiative Working Paper.

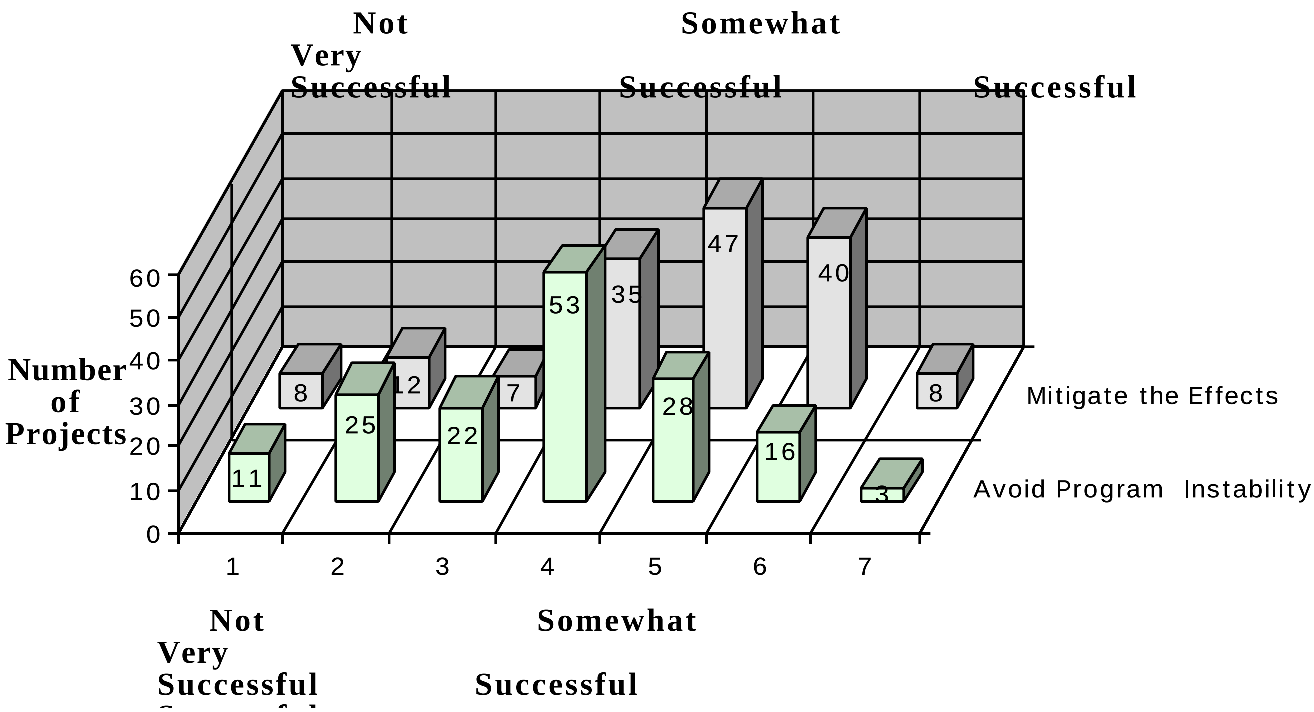


Figure 11-14: Distribution of Responses of Success in Mitigating Negative Effects of Instability (Contractor and Pentagon Surveys; Number of Projects = 158).

D. Responses to Changes

The Pentagon and Program Office surveys asked respondents to indicate the likelihood that cost, performance, and schedule would change in response to unforeseen events. The responses indicate that technical performance was the least likely to change. Significantly more likely to change were the total cost of the system and the length of the schedule. Project schedule was reported significantly more likely to change than total cost. This is consistent with the stated project objectives found in the planning phase.

Of 205 respondents, 113 indicated that schedule was more likely to change than performance, while only 46 respondents indicated that performance was more likely to change than schedule. Forty-one indicated that schedule and performance were equally likely to change. In the cost-schedule tradeoff, 83 respondents indicated that schedule was more likely to change than cost, while 56 respondents indicated that cost was more likely to change than schedule. Sixty-six respondents indicated that cost and schedule were equally likely to change. The statistical significance of the difference in the performance/schedule trade-off using the sign test is 99.99 percent. The statistical significance of the difference in cost/schedule tradeoffs is greater than 98.5 percent. These results are consistent with previously reported project objectives.

The results were similar when separating Pentagon and Program Office respondents. On average, Pentagon respondents reported that all items were slightly less likely to change than reported by Program Office respondents. The relative order of the factors was the same, and schedule was reported as the most likely to change in both surveys.

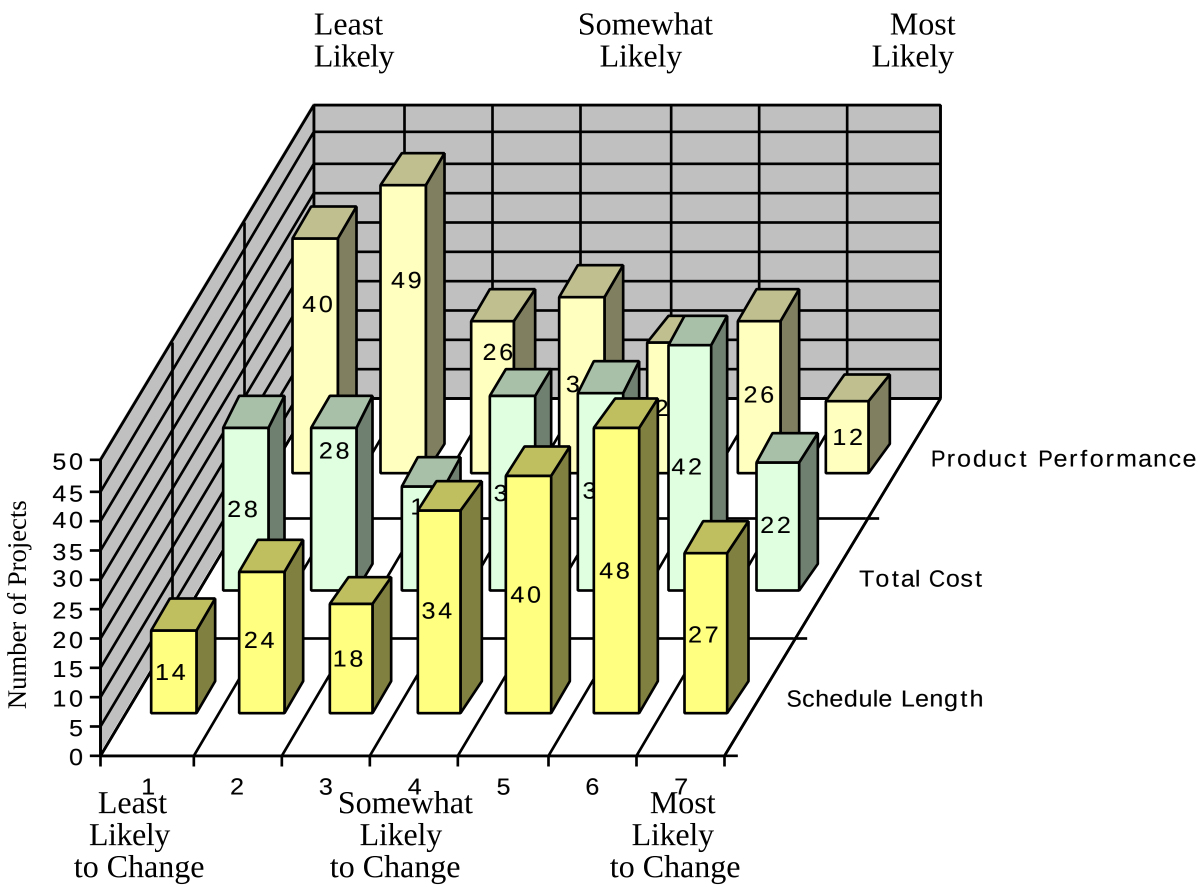


Figure 11-15: Likelihood That Cost, Schedule, and Performance Would Change in Response to Unforeseen Events to Achieve Project Objectives (Pentagon and Program Office Survey; Number of Projects = 205).

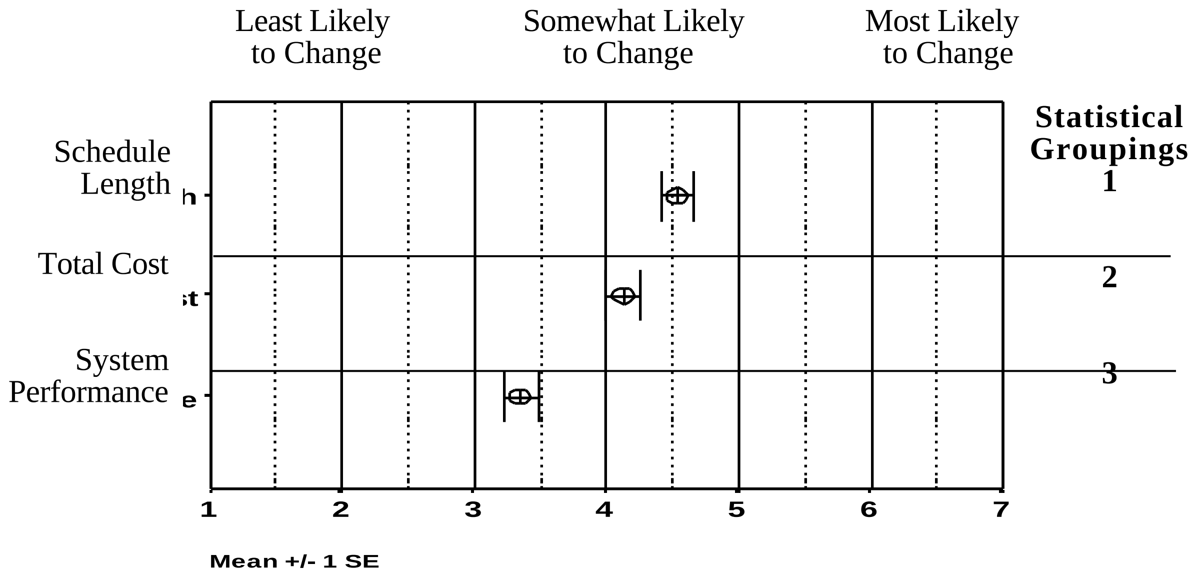


Figure 11-16: Likelihood That Cost, Schedule, and Performance Would Change in Response to Unforeseen Events (Number of Projects = 205).

Significant differences appeared between respondents working under cost-plus and those working under fixed-price contracts, but not in the relative order of the responses. For example, project managers of fixed-price contracts were more likely to change schedules and less likely to change product performance than managers of cost-plus contracts. But managers on both types of contracts reported that they were more likely to change schedules than to change performance requirements. This is consistent with the view of the schedule as the lowest project priority.

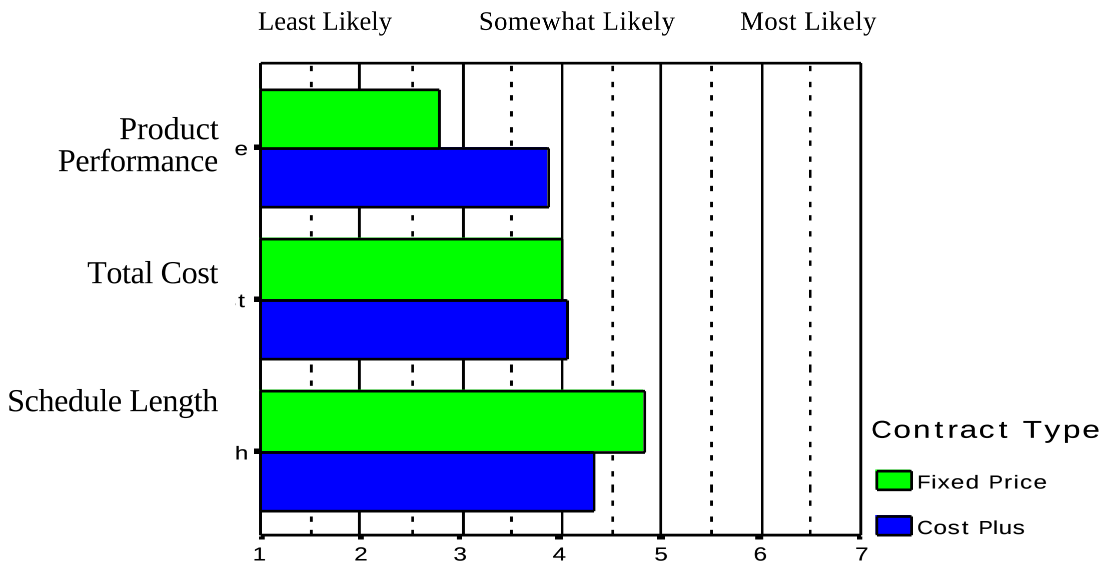


Figure 11-17: Likelihood that Cost, Schedule, and Performance Would Change by Type of Contract (Pentagon and Program Office Surveys; Number of Projects = 205).

E. Project Changes during Development

To determine the amount of change that occurs in a development project, the Pentagon survey asked respondents to indicate to what extent cost, schedule, and performance requirements had changed since Milestone 1 or its equivalent. The amount of change that occurs during the development phase is significant. The largest amount of change was reported in the budget profile and schedule areas, with significantly less change in performance requirements. This is consistent with earlier findings. One-third of all projects reported a significantly different or entirely new budget profile and schedule.

The changes in the budget, schedules, and performance requirements are not driven by external changes such as changes in the threat or mission concept. The respondents reported significantly less change in service acquisition priorities, mission concept, and threat or adversary that the system was meant to address.

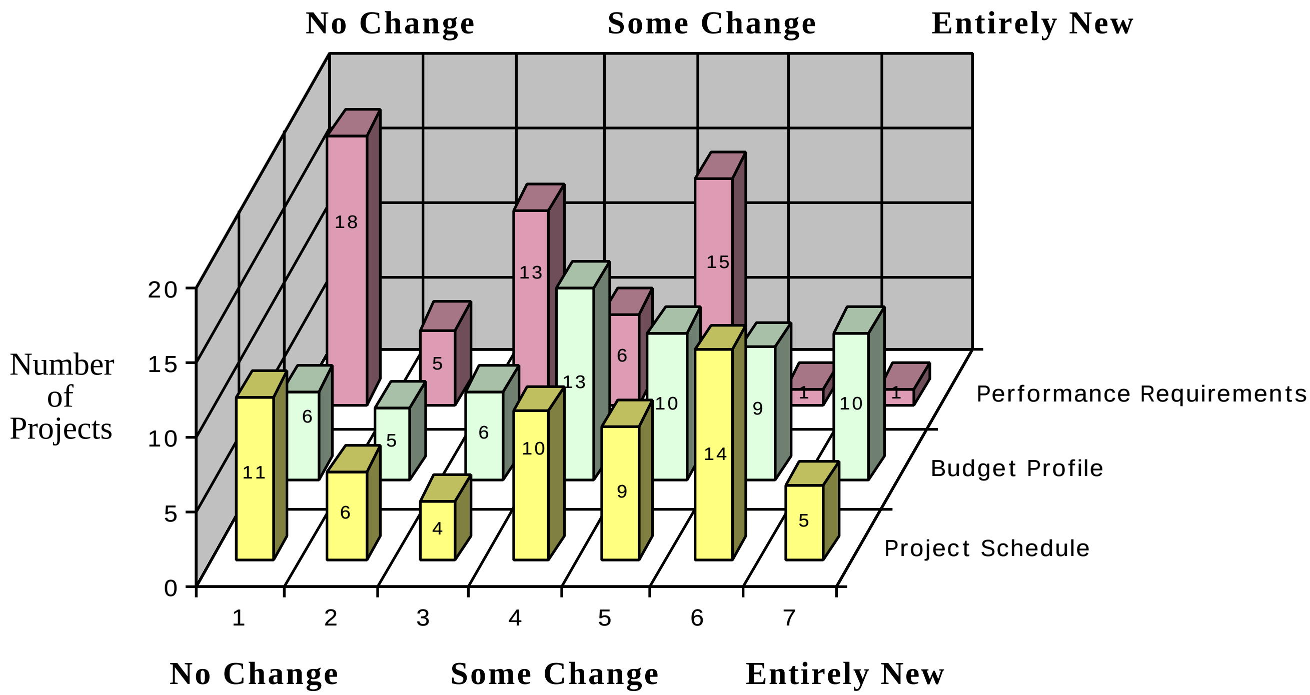


Figure 11-18: Amount of Change in Performance Requirements, Schedule, and Budget Profile (Pentagon Survey; Number of Projects = 60).

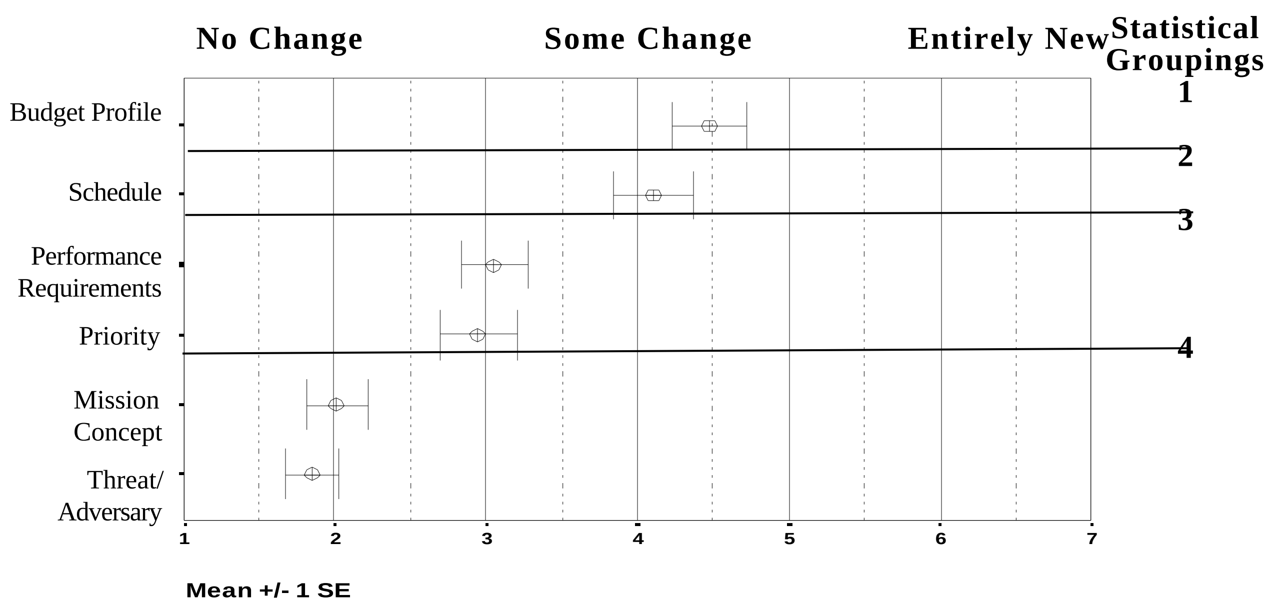


Figure 11-19: Program Changes since Milestone I or Program Start as Reported by Pentagon-Level Respondents (Number of Projects = 59).

There is a significant correlation between the reported level of change in the project schedule and the level of change in the budget profile. The Spearman correlation coefficient between the two changes is 0.72, indicating a strong positive link. This is consistent with the earlier finding that funding instability (changes in budget profile) is a primary cause of schedule slip. The correlation between changes in performance requirements and in budget profiles, and between changes in performance requirements and in project schedules, was much lower (0.35 and 0.32, respectively), indicating rather weak links. The link between changes in performance requirements and changes in the cost and schedules was also weak.

E.1. Project Schedule Changes during Development

To obtain a more quantitative measure of the frequency of schedule changes, the surveys asked all respondents to indicate the number of times schedules had been "rephased, rebaselined, or significantly altered" since the project was initiated. The responses show that a considerable number of schedule-related changes occur across many projects. Across all three groups surveyed, the number of schedule changes averaged more than two changes per project. The distribution of responses for the number of rephases per project is shown in Figure 11-20 and 11-21--which indicate that many projects have been rephased numerous times.

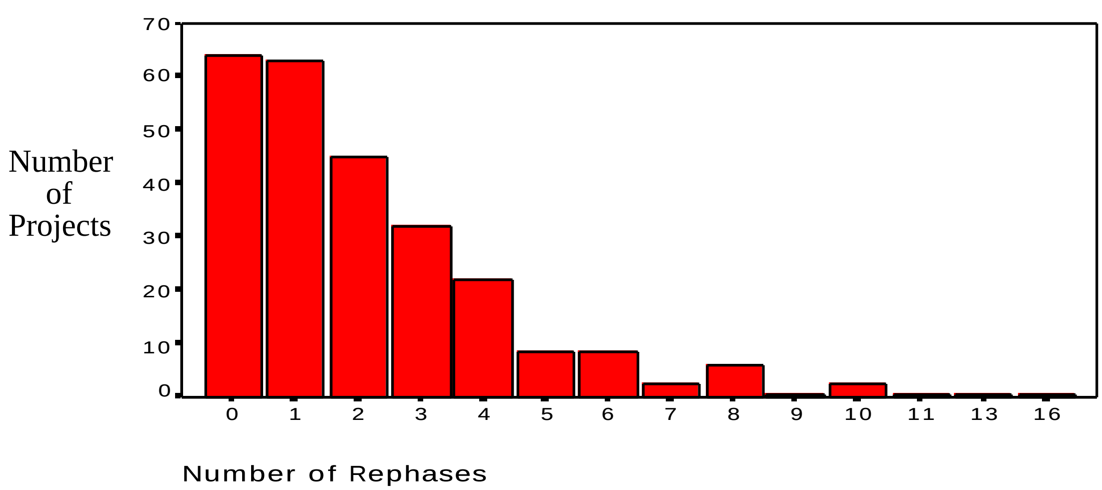


Figure 11-20: Number of Rephases, New Project Baselines, or Significantly Altered Schedules per Project from Program Initiation to Time of Survey (Pentagon, Program Office, and Contractor Surveys; Number of Projects = 260).

The responses were consistent across the three surveys. Less-than-optimal wording on the Pentagon survey may have led respondents to indicate an extra rephase, or a single rephase when none occurred.[107]

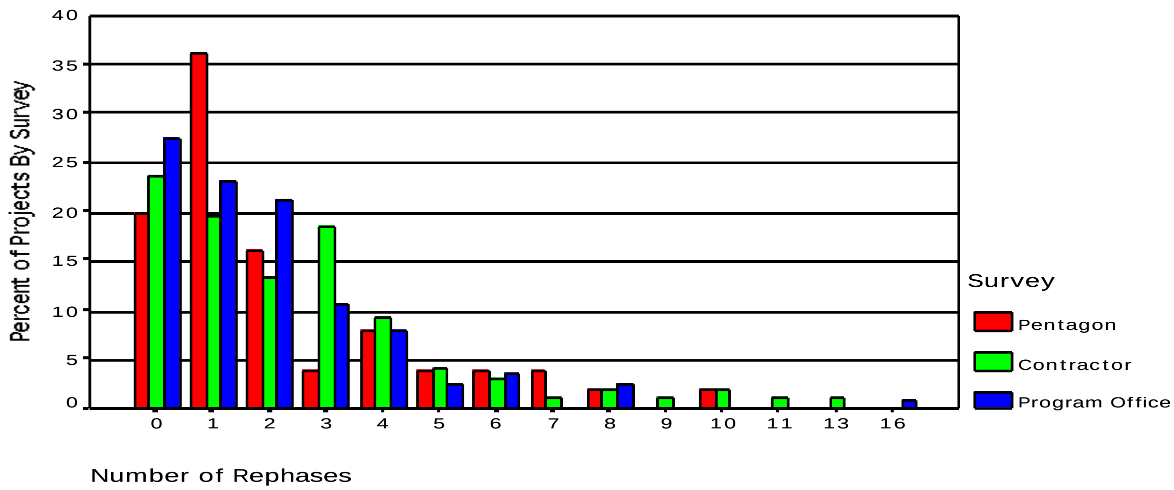


Figure 11-21: Distribution of Number of Rephases by Three Different Surveys (Pentagon N =50; Contractor N = 97; Program Office N = 113).

To determine at what point rephasing or establishment of new baselines occurs, the surveys asked respondents to indicate whether changes occurred in the pre-engineering manufacturing development phase (pre-EMD), the engineering manufacturing development phase (EMD), or the production phase. On a project-by-project basis, no systematic and significant differences were evident in the number of changes in the pre-EMD phases, the EMD phase, and the production phase. However, 45 percent of all projects were rephased twice or more solely in the EMD phase.

Several cautions are required when viewing the data presented below. First, the total number of rephases by project phase exceeded the total number of reported rephases per project. This indicates that many of the rephases affected multiple phases of a project. Second, the lower number of rephases during the production phase may be affected by the lower number of projects that have progressed into the production phase, not more stability in that phase. Approximately 50 percent of the projects had entered production at the time of the survey. None of the phases seem to be less susceptible to schedule changes than others.

---

[107] The Pentagon survey question B.11 asked, "How many times has the project been rebaselined, rephased, or significantly altered after it began" and in the space for the answer had "Total number of project baselines or project plans." It appeared that the less-than-optimal wording may have caused confusion. The answer as originally provided is used above.

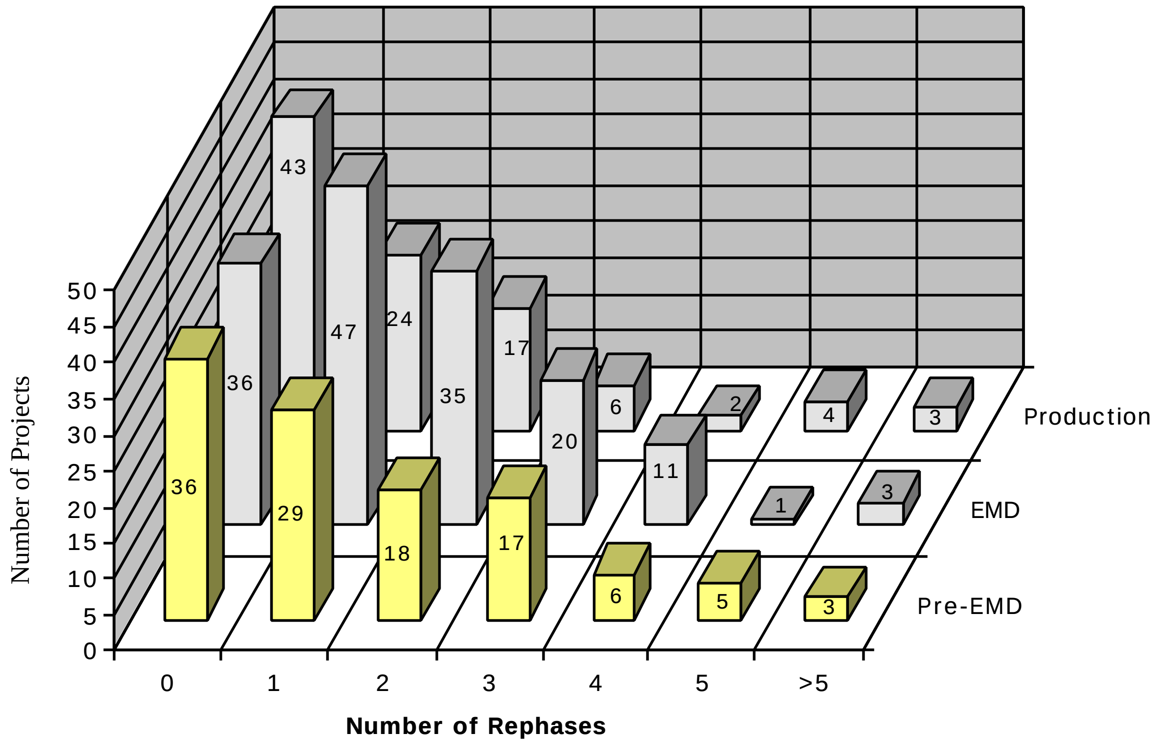


Figure 11-22: Number of Project Rephases by Acquisition Phase (Pentagon, Program Office, and Contractor Surveys; Number of Projects = 260).

E.2. Contract Changes during Development

Another measure of change in development programs is the number of contract changes. The contractor survey asked project managers to indicate both the number of contract changes and the areas that the changes affected in each phase. Only 7 of the 92 projects responding reported no contract changes. The largest number of contract changes concerned scope and requirements, followed by funding-related changes. Many contract changes dealt with schedule and the number of deliverables.

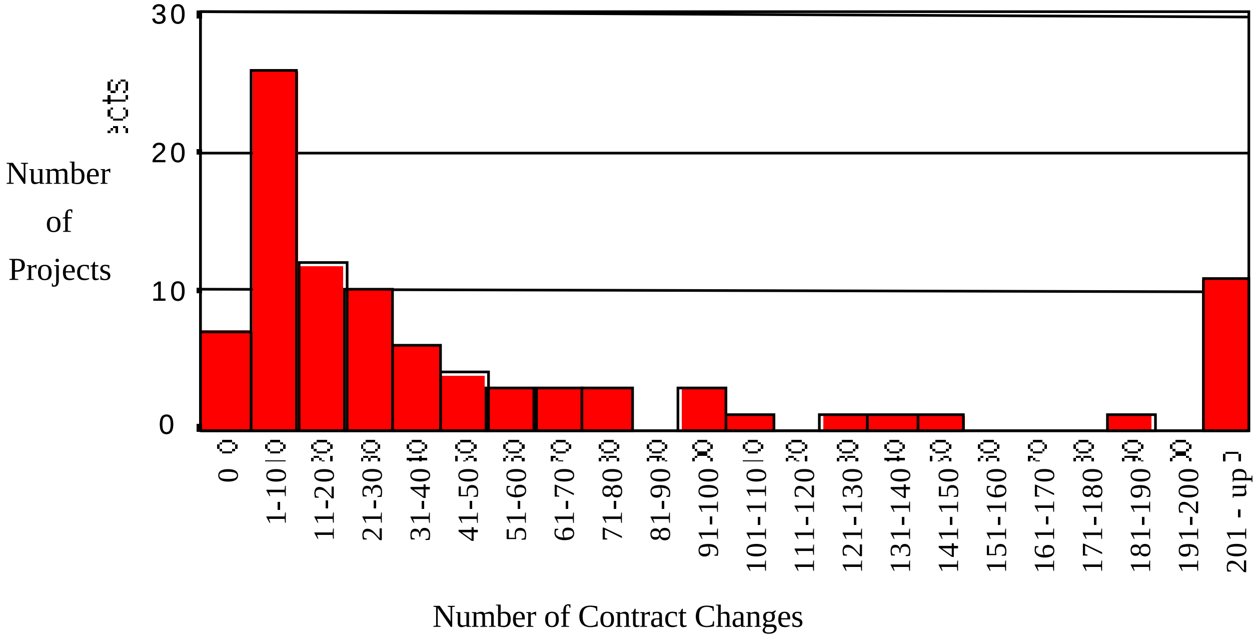


Figure 11-23: Number of Contract Changes per Project (Contractor Survey; Number of Projects = 92).

The type of contract did influence the number and type of contract changes. Managers of fixed-price contracts reported more changes in the number of production items, funding, and schedules. Managers of cost-plus contracts reported more changes relating to project scope and requirements. This is consistent with the conventional wisdom that managers can more easily change requirements on cost-plus contracts than on fixed-price contracts. A large number of changes occurred per project under both types of contracts, with each type averaging nearly 50 contract changes to date.

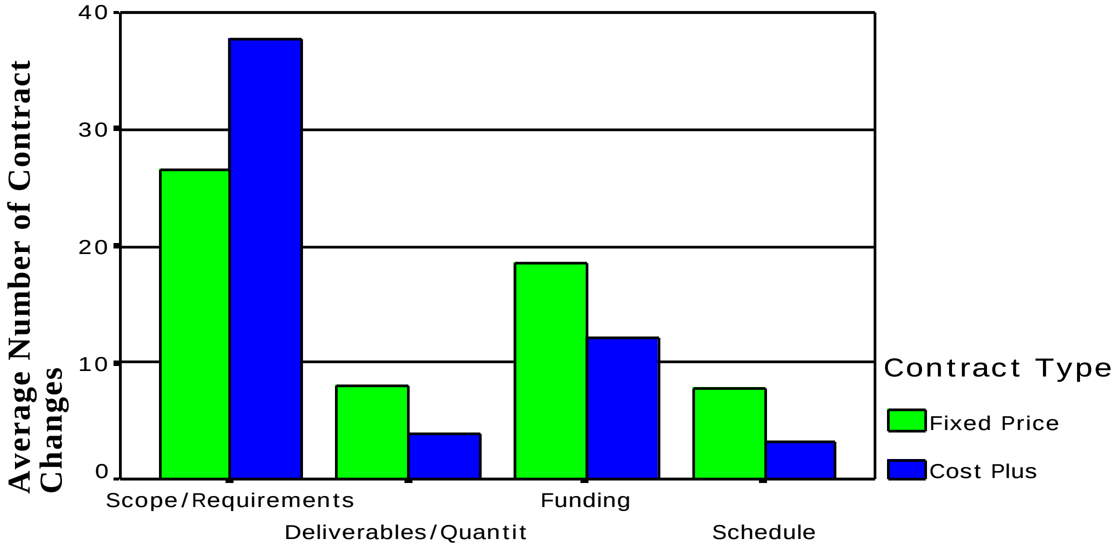


Figure 11-24: Average Number of Contract Changes per Project to Date by Contract Type and by Areas that They Affect (Contractor Survey; Fixed-Price N = 36; Cost-Plus N = 42).

Only 23 percent of respondents reported no schedule-related contract changes during the EMD phase. And only 30 percent reported no schedule-related contract changes in the production phase. Over all phases, only 18 percent of contractor respondents reported no schedule-related contract changes.

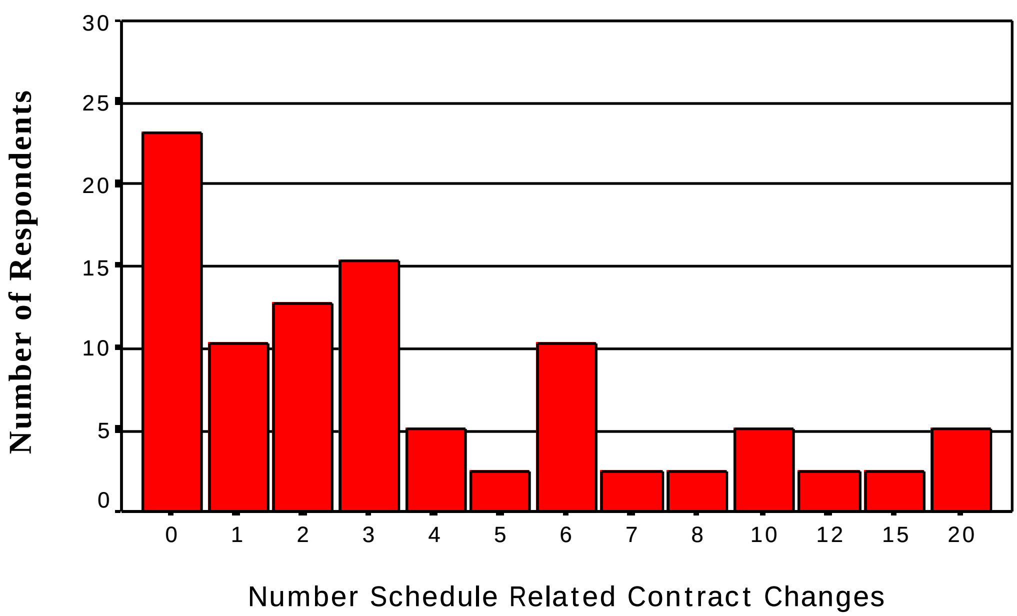


Figure 11-25: Number of Schedule-Related Contract Changes by Project in the Engineering Manufacturing Development Phase (Contractor Survey; N = 39).

Because incentives provided by the Program Office are based on adherence to the current schedule, not the original schedule, any schedule changes affect those incentives. With three-quarters of development efforts changing the contracted schedule, the few incentives for completing projects within the original contracted schedule are often lost.

F. Barriers to Shortening Project Schedules

The Pentagon and Program Office surveys asked respondents about the difficulty of shortening project schedules, the amount of time required to obtain approval for a shorter schedule, and the likelihood of gaining that approval. The surveys also asked about the factors entailed in deciding whether to approve shorter project schedules, and in evaluating the technical possibilities for shortening a project.

F.1. Lengthening versus Shortening Project Schedules

The Program Office survey asked two questions about the difficulty of lengthening or shortening project schedules by 20 percent. Project managers reported that it was much easier to lengthen a project's schedule than to shorten it. For example, 70 percent said it was very difficult to shorten schedules, while only 19 percent indicated that it was very difficult to lengthen the schedule. In all, 111 project managers stated that it was more difficult to shorten a program than to lengthen it, while only 25 project managers reported the opposite. Twenty-five project managers reported that it was equally hard to shorten or lengthen the schedule.

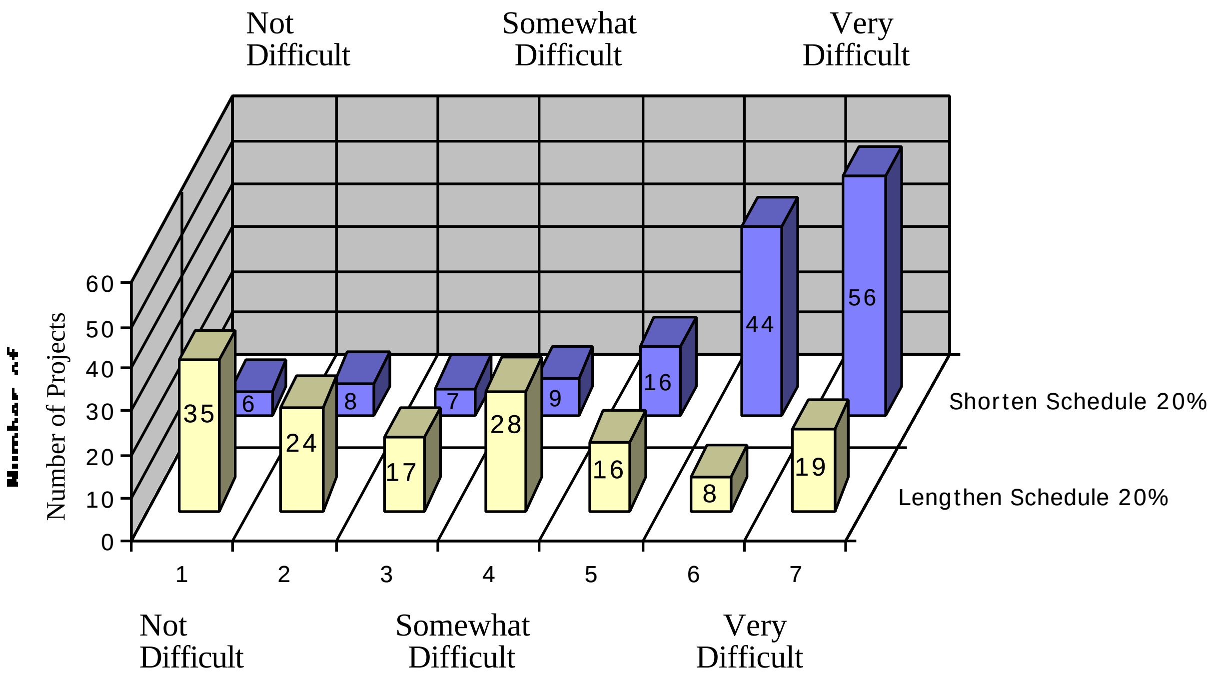


Figure 11-26: Ease of Shortening or Lengthening a Project Schedule by 20 Percent, as Reported by Government Project Managers (Program Office Survey; Number of Projects = 146).

In follow-up interviews, both government and contractor managers confirmed that it is significantly more difficult to shorten project schedules than to lengthen them. The reasons and incentives for shortening schedules would therefore have to be relatively strong to induce project managers to attempt to do so. As shown earlier, the incentives to try to shorten schedules are not strong. The reason it is more difficult to accelerate than to lengthen a project schedule will be explained next.

F.2. Critical Factors in Shortening Development Schedules

The Pentagon survey asked respondents to rate factors influencing their decision to approve or disapprove a contractor's proposal to shorten a project schedule by 25 percent. The question specified that the new schedule would require the same amount of development funding. The respondents indicated that the most important factor in such a decision was the ability to change the production funding profile, or in what year the money was available to be spent. The next-highest consideration was changing the development funding profile. The lowest-rated item was obtaining the user's approval to accelerate the schedule. Figure 11-27 shows the number of responses indicating that a specific factor would be either critical or a non-factor in deciding whether to approve a schedule reduction. Some factors such as training and logistics issues did not play a significant role, in the view of respondents. The primary drivers appeared to be funding issues and the Program Office's ability to meet the new expectation for budget and schedule.

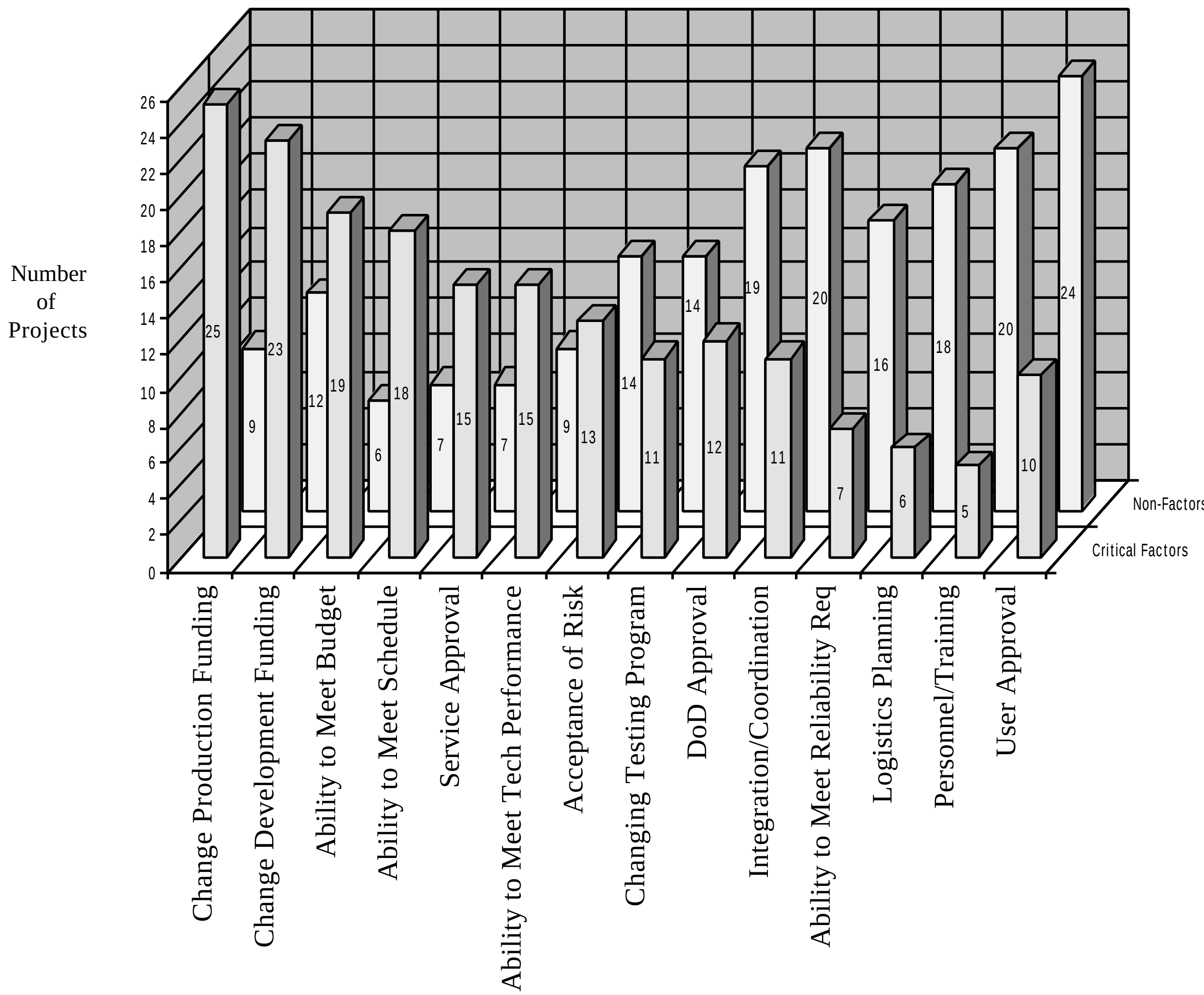


Figure 11-27: Factors Critical and Not Important in Decisions to Approve or Disapprove a Contractor Proposal to Shorten Project Schedule 25 Percent (Pentagon Survey; Number of Projects = 48).

F.3. Time Entailed in Decisions to Reduce Project Schedules

To identify some of the barriers to shortening project schedules, the Pentagon and Program Office surveys asked how long respondents estimated it would take to approve a contractor's proposal to shorten the project schedule by 25 percent, given the same amount of total funding. The average time required to obtain either approval or disapproval was reported to be 6 months.

While many projects indicated that a decision could be reached in 3 months or less, many other projects indicated that it could take significantly longer.

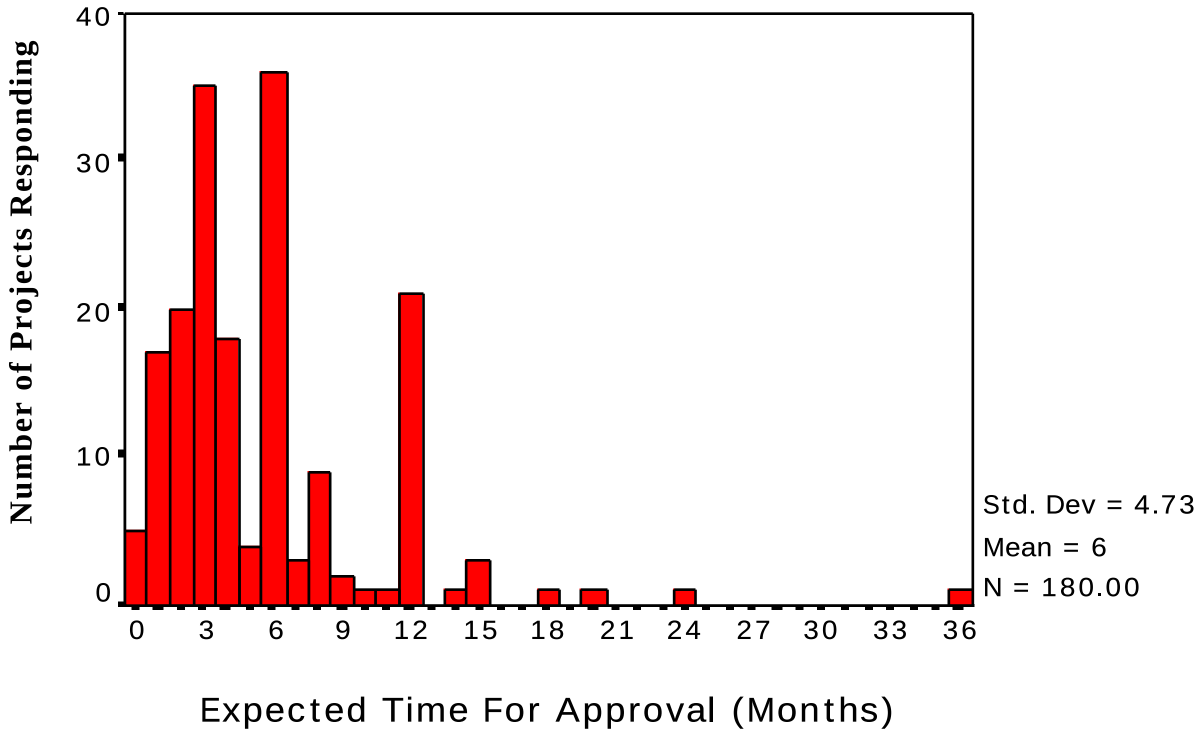


Figure 11-28: Estimated Time to Approve or Disapprove a Proposed Reduction in a Project's Schedule, Given the Same Amount of Total Funding (Pentagon and Program Office Surveys; Number of Projects = 180).

F.4. Probability that a Schedule Reduction Will Be Approved

The Pentagon survey also asked respondents to specify the probability that a contractor proposal to reduce project schedule by 25 percent would be approved, given the same total funding. The average of the reported probability was 49 percent, but that figure does not tell the entire story. The largest number of managers reported that a proposal to shorten the schedule would not be considered let alone approved, and the second-largest number stated that such a proposal stood only a 50 percent chance of being approved. Only 8 of the 41 projects responding indicated a 90 percent or greater chance that a proposal would be approved, and only 15 of 41 indicated that it stood a 60 percent or greater chance of approval.

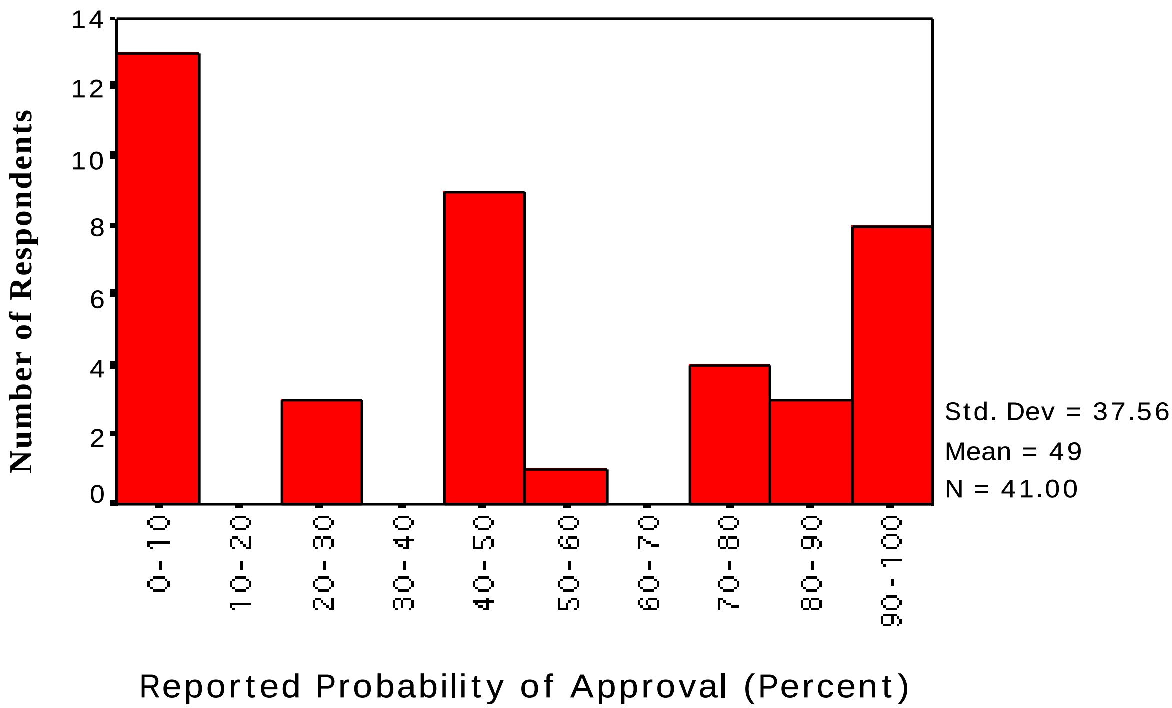


Figure 11-29: Program Element Monitors' Estimate of the Probability That a Proposed Schedule Reduction Would Be Approved, Assuming the Same Total Funding (Pentagon Survey; Number of Projects = 41)

The Pentagon survey also asked respondents to note the factors they primarily consider in deciding whether to approve of a schedule reduction of 25 percent. The primary consideration most often cited was the availability of funding--named in 55 percent of responses. The ability to develop the product and to accept program risk was the primary consideration in 29 percent of the projects. Operational considerations were mentioned by 16 percent of respondents. These results are supported by another question revealing that schedules for 77 percent of all projects are limited by funding, not by technology or engineering-related aspects.

Summary of the Analysis of Development Schedules

Changes in annual funding levels, technical problems, and revisions in user requirements most often drive changes in development plans. The project schedule is the most likely aspect to change in response to these unforeseen events. Development projects average two significant schedule rephases. When schedules change, they are relatively easy to lengthen and very difficult to shorten.

The primary concern when shortening project schedules is the availability of production and development funding. Program element monitors estimated that a decision on a contractor proposal to shorten the project schedule by 25 percent would take an average of 3 months and as long as 3 years, even if such a change would not require an increase in total funding. Program element monitors' estimate of the probability of obtaining approval to shorten a project's schedule by 25 percent was 50 percent, even without any increase in total funding.

One result of schedule-related incentives was that development efforts usually either slip or end exactly on schedule. Over 39 percent of all projects finished within 3 months of their schedule, and 30 percent were exactly on schedule. Less than 5 percent of projects finished ahead of schedule. Respondents attributed the primary cause of schedule slip to funding instability. Only 20 percent of all projects, and 30 percent of projects reporting schedule slips, named technical problems as the primarily reasons for schedule slips. This further indicates that technical requirements are not the primary driver in a majority of development projects.

Program Office and Pentagon respondents indicated that significant reductions are possible if schedules are given significant priority and required funding is made available. On average, the Program Office managers estimated that, if needed, projects could be completed in roughly half the remaining schedule. Pentagon respondents estimated that the time required to develop the project without resource constraints was 73 percent of the planned schedule.

The influence of the planned and contracted schedule on the length of the development period is evident in the fact that few projects are ever completed ahead of the initial schedule. The schedule established early in the project's planning stage essentially sets the minimum time it will take to complete the project. As shown in earlier chapters, the initial project schedule is not based primarily on development-related requirements but rather on the expected availability of funding. Once the initial schedule is established, incentives throughout the contracting and development phases encourage managers to meet the planned schedule and not reduce it. The outcomes of project schedules show that this is the case.

Part 4

Conclusions, Observations, and Recommendations

Part 4: Overview

Part 4 draws conclusions from the research results on the project level and makes observations regarding the overall development process. These lead to specific policy recommendations on the steps considered necessary to shorten development times for new military systems.

Chapter 12 discusses the schedule development process and draws specific conclusions on that process based on the research. Chapter 13 makes observations on the overall development processes that can be drawn from the research and identifies key problem areas that must be addressed to reduce development time. Chapter 14 presents specific recommendations for addressing those problems. Chapter 14 concludes with a discussion of the potential changes in weapon development strategies made possible by dramatically shorter development times.

Chapter 12

Conclusions Regarding the Process Used to Develop and Execute Project Schedules

Data from the three surveys and discussion of the process used to develop and execute the project schedule lead to conclusions about the impact of the schedule on the eventual outcome. These conclusions are based on information from 317 separate projects as well as interviews conducted at the Pentagon, Program Office, and contractor levels. While these results do not represent what occurs on a specific project under specific circumstances, they do represent the processes used across the great majority of Air Force development projects.

These conclusions can yield specific recommendations on how to change the schedule development process and the organizational focus to shorten the time required to develop new projects.

Conclusion 1: Short development times are not a significant priority for military development projects.

Despite the fact that 80 percent of Pentagon program element monitors report that users want systems "as soon as possible," and that 70 percent of projects are needed to meet current operational deficiencies (Figure 8-2 and 8-3), shortened schedules most often rank fourth of four project objectives (Figure 8-5). This goal ranked significantly lower than bettering project performance and lowering acquisition cost. As shown in Figure 8-6, only 15 percent of Program Office project managers and Pentagon program element monitors ranked short schedule very important; over half of the respondents indicated that a short acquisition cycle was only "somewhat important" or "not important."

The lack of priority placed on schedules can also be seen in the contracting process and the criteria used to select the contractor. As shown in Figure 9-9, 65 percent of project managers and program element monitors indicated that development time was only "somewhat important" or "not important" as a criterion for selecting a contractor. Figure 9-10 reveals that the vast majority of contractors indicated they had no incentive to bid a shorter schedule.

The results are seen in projects' schedule-related results. Figure 11-1 and Figure 11-4 reveal that very few projects are completed ahead of schedule--despite the estimate by project managers, shown in Figure 11-8, that the average project could be completed in half the time remaining and the estimate by the program element monitors that the programs could be completed in 65% of the original planned time as shown in Figure 11-9.

From these results and analysis across the planning, contracting, and development phases, I conclude that shortening development schedules is not seen as a high project priority within the current Air Force development system.

Conclusion 2: The initial project schedule has significant influence on the minimum time taken to develop a project.

The effect of the initial project schedule can be seen in the contracting and development phases. As shown in Figure 9-2, 80 percent of requests for proposals specify an expected project schedule. As revealed in Figure 9-5, the Program Office's expected schedule becomes the primary input to the contractor's proposed schedule. As shown in Figure 9-6, 66 percent of contractor respondents indicated that the initial schedule was the sole determinate, or nearly the sole determinant, of their proposed schedules. Figure 9-10 shows that contractors say they have no incentive to bid a schedule different from the one the Program Office expects. Figure 9-12 and 9-13 shows that a large majority of schedules proposed by contractors exactly match the government's expected schedule. These proposals form the basis for development contracts.

In the development phase, the objectives of the Pentagon, Program Offices, and contractors are primarily to meet cost, schedule, and performance goals and not to exceed them. Figure 10-11 shows few incentives for Program Offices to shorten schedules, while Figures 10-16 and 10-17 show that the Program Offices provide few incentives to contractors to meet or shorten project schedules. Figure 10-18 shows that the contractors, in turn, feel little incentive to exceed project objectives.

Chapter 11 similarly revealed little evidence of any incentives to exceed, as opposed to meeting, a project's cost, schedule, and performance goals at the Pentagon, Program Office, or contractor levels. As shown in Figure 11-1, 39 percent of surveyed projects are within 3 months of their initial schedule. Very few--less than 5 percent--report being ahead of schedule. As illustrated in Figure 11-4, these results are consistent with information in the RAND database drawn from selected acquisition reports for all major defense projects.

From these data showing the clear links among the initial project schedule, the contracted schedule, and the resulting development time, I conclude that the initial project schedule has a significant impact on the minimum time it takes to develop a project.

Conclusion 3: Initial project schedules are determined primarily by expected development and production funding rather than development-related requirements.

This conclusion is supported by results from many questions in the three surveys. Figures 8-13, 8-14, and 8-15 show that the user's desired date, expected development funding, and expected production funding were the most significant influences on the length of a project's initial schedule at both the Pentagon and Program Office. But the process for allocating resources described in Chapter 3 and significant discussions outlined in Chapter 8 reveal that the user's desired date is determined primarily by the availability of funding.

Figure 8-16 shows that 77 percent of respondents report that their schedules are limited by funding, not technology or engineering. Tables 8-8 through 8-10, and Figures 8-17 through 8-20, show that expected development funding rated more important on more projects than engineering requirements, technology development, and development of the manufacturing process in every category, including size of project (ACAT I, II, III levels), type of project (aircraft, spacecraft, electronic, missiles, software, or other), and amount of technological advance (revolutionary product, new generation, or incremental improvement).

As shown in Figure 8-22, the information most influencing development of the initial schedule is expected development funding and expert judgment. Contractor proposals, historical similar projects, bottom-up schedule development, and parametric modeling were all reported to have less impact on development of the initial schedule. Comparable commercial development efforts were rated significantly lower than any other factor.

Figures 11-5 and 11-6 underscore the fact that a majority of respondents report the primary cause of schedule slips to be funding instability and changes in requirements, not technical problems. If technical development issues were the limiting factor, one would expect more than 20 percent of projects to report technical problems as the primary cause of schedule delays (see Table 11-1).

Based on this information, I conclude that the length of the initial development schedule is primarily determined by the amount of expected funding for a project, and not development-related requirements.

Conclusion 4: There are few incentives at any level to reduce project schedules and development time.

This is evident from responses regarding project objectives in the planning phase, incentives during the proposal stage, and incentives at the Pentagon, Program Office and contractor levels during development.

The incentives associated with a project begin with its objectives. As shown in Figure 8-5, Figure 10-5 and Figure 10-8, short schedules are the lowest priority compared with increasing performance and cutting acquisitions and operating costs, in both the Pentagon and the Program Offices.

Figure 9-9 shows that 65 percent of project managers and program element monitors did not report development time as an important criterion in selecting contractors. In Figure 9-5, contractors reported that the government-proposed schedule was the primary consideration, and in many cases the sole determinant, in their proposed schedules. Figure 9-10 shows that the contractors felt “no incentive” to bid a schedule different from the government’s expected schedule, and Figure 9-11 shows that this was consistent for both competitive and sole-source contracts. Figure 9-12 and Figure 9-13 show that the vast majority of proposals exactly match the government’s expected schedule.

The incentives during the development stage to reduce development time are also reported to be small. As shown in Figure 10-5, Pentagon respondents indicated that the first and second goals of a project are to increase performance and lower cost. Shortening schedule was reported as the fourth of four objectives at the Pentagon and Program Office levels. As shown in Figure 10-10 the incentives provided to the Program Office primarily center on meeting project objectives and not exceeding them. As shown in Figure 10-11, in over half the projects the Program Office project managers are reported to have no or even negative incentives to shorten cycle time.

Contractors’ incentives to shorten cycle times are similarly weak. As shown in Figures 10-16 and 10-17, Program Offices reported that in a vast majority of projects, contracts do not include any financial incentive for on-time or early completion of the project. In Figure 10-18 contractors reported that they feel no incentive to exceed any project goals. Figure 10-20 also shows that 73 percent of contractors reported no or negative customer-provided incentives to shorten project schedules. In only 18 percent of the cases did contractors indicate that the Program Office provided more than a slight incentive to shorten schedules. Figures 10-21 and 10-22 show that the type of contract (fixed-priced or cost-plus) or the presence of competition had little or no effect on the incentive to reduce schedule provided by the government. As shown in Figure 10-28, contractors involved in fixed-price contracts did report slightly higher levels of overall incentives than those on cost-plus contracts.

Based on this information, I conclude that there is a lack of significant incentives at all levels to shorten project schedules and development cycle times.

Conclusion 5: There are significant structural, cultural, and organizational barriers in the schedule development process that inhibit shorter schedules.

Once a project is under way, project managers consider shortening the schedule very difficult, as Figure 11-26 shows. Figure 11-27 similarly reveals that program element monitors believe the critical factor in deciding whether to approve a proposal to accelerate a project is the ability to change production and development funding profiles. As shown in Chapter 3, the development funding process is elaborate, cumbersome, and difficult to change late in the budgetary process. Figure 11-28 shows that Program Offices and program element monitors estimate that 6 months would be required for a decision on a contractor's proposal to shorten a project's schedule by 25 percent, even without any increase in total project funding. As shown in Figure 11-29, program element monitors estimated the average probability of approval for a proposal to shorten schedules without increasing total program funding at 49 percent. The largest number reported the chance of approval at 0 percent. The primary consideration was the availability of changing funding. This is consistent with Figure 8-16, which shows 77 percent of the projects report to be funding limited as opposed to technology or engineering limited.

The cultural barriers begin with the low priority placed on project schedules: they are seen as dictated by funding-related decisions and technical requirements. Schedule-related feedback from Program Offices and defense contractors is limited primarily to when the schedule cannot be met. Once schedules and funding are determined, Program Offices do not have the authority or ability to adjust allocated resources to match the optimal project schedules. The result is that available funding drives the schedule, but the possible schedule does not appear to drive funding decisions.

Based on these factors I conclude that there are significant structural, cultural, and organizational barriers to shortening cycle times. Within the schedule development process, significant hurdles block effective feedback on schedule-related issues.

Review of the Data and Conclusions

The data and conclusions from this research were presented to a number of organizations as an aid to interpreting their validity. Representatives from the acquisition reform offices within the Pentagon, the Aeronautical Systems Center, and the Electronic Systems Center agree significantly with the information.

The results and conclusions were also presented to representatives from government organizations, program offices, and representatives from the major defense aerospace companies at the Lean Aircraft Initiative Plenary Workshop in October 1997. Following the presentation, each group was asked to review the data from one of the development phases in detail and then asked to report, through a written survey, whether the results and conclusions of the research matched their personal experience. The results were surprising only in their near-unanimity: among 90 responses, 88 people reported that the data matched their personal experiences. Only 2 reported being neutral on whether the data match their experiences. No one reported that the data and conclusions were contrary to their personal experiences.

Does the Data and Conclusions Match Your Experiences?

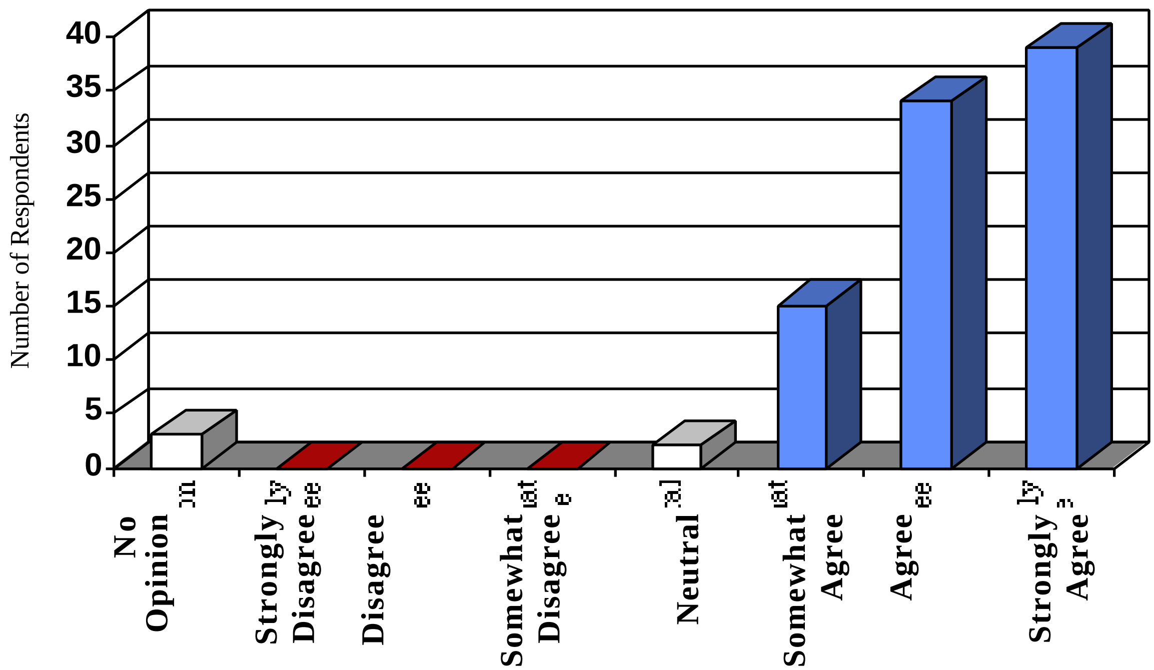


Figure 12-1: Responses from the Lean Aerospace Initiative Plenary Workshop as to Whether the Data and Conclusions Match Their Personal Experience, LAI Plenary Session Hartford CT, 8 October 97 (Number of Respondents = 90) .

Summary

Based on the analysis of survey data on 317 projects drawn from a wide cross section of current development efforts, and the strong acceptance of the results and conclusions of the research by those experienced in the defense acquisition processes, the data and conclusions must be accepted as accurately representing the processes and procedures used to develop and execute project schedules. The data and conclusions, while not representing what occurs on a specific project under specific circumstances, do represent the general processes employed across the great majority of Air Force development projects. The conclusions on the schedule development process and its impact on development time lead to specific observations and recommendations on how to change that process and organizational focus to shorten development time.

Chapter 13

Observations on the Overall Product Development Process

The overall observations of the defense product development system focus on four specific areas: a lack of clear and consistent leadership on schedule reduction; the lack of schedule-based information from which to make decisions; the lack of schedule-based incentives at all levels; and the overriding influence of the funding process. Within each area, specific observations about the development system will lead to specific recommendations addressed in the next chapter.

1. Lack of Leadership on Cycle Time

Observation 1A: There has been little leadership or emphasis on reducing the time to develop new products, and shortening development time is not seen as an important priority.

Development organizations focus on increasing performance, reducing cost, and staying within the allocated budget. Schedule is most often seen as an outcome of these other objectives and not something to be actively managed. The reason is that there is no consensus on or appreciation of the impact of cycle time within the development community. The survey and interviews indicate this at all levels, from senior Air Force and DoD leadership down to project engineers. The most prevalent view at each level is that shortening schedules is a low priority.

I believe the reason for this view is the significant lack of reliable information on which to base judgments. Those interviewed view cycle time as it affects their job and their organizational goals; their experiences and the limitations they face do not allow them to see how long cycle times affect the development process, cost of systems, or military capability as a whole. What is clear is that no one has made a clear and compelling case for reducing cycle time for military projects. No rationale has been presented connecting the issue of cycle time to warfighters' capabilities. No case has been made on the effects of long cycle time on the budget. No case has been made on the effects of long development times on the acquisition community. Without a consensus among key personnel on the importance of reducing development times, little progress will be made on reducing them.

Observation 1B: There is no visible or widely held goal of reducing cycle time.

Throughout this research effort, no goals related to reducing cycle time were found to be accepted or used across any of the services or development organizations. Significant goals are associated with increasing performance and reducing cost--survey respondents rate them as the first and second priorities.

Observation 1C: There is no advocate for reducing cycle time.

Users, whom one would expect to be the strongest advocates for shortening development time, have not made doing so a priority. Instead users have traditionally stressed better system performance and improvements in reliability, maintainability, and supportability, and focused on starting additional projects rather than on reducing development times. The acquisition community has traditionally advocated new technology and systems, although it is now focusing on cutting acquisition and life-cycle costs as part of reform efforts. The budget and oversight communities have also stressed annual cost reductions and accountability. No organization was found to be a strong advocate, or to have responsibility, for shortening development times.

2. Lack of Schedule-Related Information and Tools

While significant effort is placed on determining the required cost of a proposed project, relatively little emphasis has been focused on accurately determining the required schedule. As shown by the research, project schedules are based to a greater extent on expected funding; relatively little effort by the Pentagon, Program Offices, or defense contractors is devoted to analyzing the appropriateness of schedules vis-a-vis development-related requirements. This absence of rigor stems from the overall lack of emphasis on schedules, the lack of reliable information, and the lack of effective tools for analyzing schedules.

Observation 2A: Schedules are based on factors other than the actual time required to develop a project. Once established, these schedules determine the minimum time it will take to develop a product.

Project schedules are not based primarily on the time required to develop the project, as determined by technological and engineering requirements and the manufacturing process. Instead, schedules are determined primarily by expected development and production funding. This was found consistently across all sizes and types of projects. These schedules determine the minimum time that it takes to develop a project, since very few are ever completed ahead of schedule. Once established, the initial project schedule becomes a self-fulfilling prophecy.

Observation 2B: Little rigorous schedule-based information is available to plan, manage, or evaluate timetables for development projects.

This research entailed significant efforts to locate detailed schedule-based information, but little such information other than the resulting schedules was found for most projects. The only schedule information generally available is based on acquisition milestones or major events, which do not evaluate the appropriateness of the schedules or allow comparisons among projects. The scheduling rationale and possible alternatives are typically not documented. Several other researchers have made similar observations.[108] The schedule information that is available concerns funding. Thus, schedule becomes the output, or dependent variable, of the cost and performance of the project.

The lack of schedule-related information makes it difficult to evaluate the feasibility, risk, and appropriateness of alternatives. With little supporting data and analysis, discussion and decisions are based mainly on people’s limited experiences and judgment, and on elaborate cost models.

[108] RAND’s Smith and Drezner. AFIT Hazeldean and Topfler.

Observation 2C: There are no effective, accepted, or widely used schedule-estimating tools for military development projects. The lack of such tools limits the ability to make decisions based on good information.

The lack of rigor in methods used to develop initial schedules can be attributed partly to the lack of available and easy-to-use schedule-estimating tools. The research turned up no scheduling guides or standard references for devising a breakdown of activities and their expected duration. Tools dependent on information from other projects, such as bottom-up schedule development (based on engineering requirements), comparison with historically similar programs, and parametric modeling, are not used. Comparisons with other programs are difficult because very limited schedule-related information is available.

The surveys indicated that no project had made significant use of schedule-estimating tools or parametric models. Most rely instead on rudimentary Gantt and milestone charts. Though many projects reported “occasionally” using critical path management tools or PERT, fewer than a third (40 of 126) reported extensive use of either in developing the initial project schedule. No other scheduling tools were found to be widely used to forecast development time based on the project’s development-related requirements.

The lack of emphasis on scheduling tools stands in stark contrast to the effort placed on estimating costs. Several major organizations at both the DoD and the service levels have been established to develop and maintain detailed cost models, which are used to ensure that a development effort can be accomplished within the allocated budget. The cost models do not estimate project schedules or the cost of development time. Based on discussions with cost analysts in the DoD and each of the three services, I conclude that these models are not significantly affected by the length of the project schedule, except in a few minor areas. People in charge of such models estimated that the models would predict that doubling a project schedule would increase a project’s total cost by 5 percent, owing to higher managerial costs to the contractors.[109] To achieve such dubious results, the cost models ignore many important considerations.

One such consideration is the fact that the longer a project lasts, the more its costs grow. Among the projects surveyed the average cost growth owing to funding instability and requirement changes alone was 4.6 percent per year. The reported total annual cost growth was 6.4 percent. The RAND database shows that annual cost growth for major defense acquisition programs

[109] Interviews with representatives from the DoD (Cost Analysis Improvement Group, CAIG) and the various service cost estimating organizations were conducted during the spring of 1998 at the Pentagon.

averages 5.2 percent.[110]

The models also fail to include the opportunity costs of delaying a system's availability. Because these models use costs largely as a fixed input and not an output, they are not capable of estimating required or optimal schedules, or of determining the impact of various schedules on cost.

Previous attempts to identify relationships based on project characteristics have proven largely unsuccessful and have been hampered by lack of data, and have not had an impact on development times. The data that are available do not separate the effect of funding limitations from technical limitations. Most schedule-related efforts have tried to identify the causes of schedule slip, not the adequacy of the planned schedule. Without detailed schedule-related information and tools to analyze it, scheduling decisions will continue to be unsupported. And schedule-based arguments are not likely to have the impact of other cost-based arguments backed by analysis.

Observation 2D: Contractors base their proposed schedules on the government's expected schedule, not on analysis of the actual time required to develop the product.

Not only did contractors propose development plans to meet the Program Office's expected schedule, but those that did analyze the required schedule reported that it had less than a moderate impact on their proposed schedule. Contractors did not report using any effective schedule development and analysis tools, nor were any observed.

Bidding a different schedule than that calculated by the Program Office is not seen as a winning strategy. Program Office project managers stated that different schedules are presumed to carry higher risk or be non-responsive. Without detailed information on the contractor's proposed schedule and the ability to analyze it effectively, there is no way to refute this assumption.

3. Lack of Schedule-Based Incentives

The surveys uncovered few incentives associated with reducing development times at any level of the development process, at the Pentagon, Program Offices, or contractor levels. The few incentives that do exist are associated with meeting but not beating project cost, schedule, and

[110] Calculated from the RAND SAR database from the development cost estimate and the actual or current projected cost for 72 MDAP programs.

performance goals.

Observation 3A: There are no effective incentives for reducing development time at either the Program Office or the Pentagon levels.

The lack of schedule-based incentives stems partly from the lack of priority placed on development time and shortening project schedules. No metric or measurement is used to track schedule performance across the range of projects in development. Few visible metrics are used to track a specific project's schedule performance other than its current, though often changed, plans. Project slips are viewed as based on budget cuts or technical problems.

Project managers are apparently not held accountable for schedule slips, reporting that schedule performance had little effect on their performance rating and promotion potential. One reason there is little schedule-related incentive is the high turnover rate for Pentagon program element monitors and Program Office project managers. The average program element monitor has held that position for fewer than 15 months, the average program manager for fewer than 18 months. These tenures are short compared with the average 75-month development time for surveyed projects. High turnover means that accountability for schedule performance is spread among a number of people, making it difficult to hold anyone responsible. The schedule incentives that project managers do report are based on meeting the planned schedules.

Observation 3B: There are no effective incentives for contractors to reduce development times.

The strong incentives that companies report during the contracting phase are to match the government's expected schedule and not to change it. The result is that nearly all proposals match exactly the government schedule. Similarly, contractors report few or no incentives to beat schedules as a project proceeds. The schedule-based incentives that do exist are based on meeting the schedule.

Observation 3C: No effective measures are used to evaluate schedule performance across different organizations, or within the development process as a whole.

The lack of schedule-related incentives appears to stem partly from the conspicuous absence of metrics for many projects. The only schedule-related metric found to be used was whether the project met its planned schedule, and how much slip had occurred. And the limited schedule data that are available are used on a project-by-project basis only. No attempt at any level was found to look at schedule performance across a portfolio of projects, including among different development centers, mission areas, or defense contractors. Thus, no one knows whether one organization is doing better or worse in terms of schedules, or whether one approach is more effective than another. Without metrics, it is also impossible to determine the schedule-related performance of the development system as a whole.

Observation 3D: No effort is made to compare a project's development time with the time that should be required to develop it.

Tied to the issue of schedule-related incentives is the difference between planned development time and required development time. No effort was found to identify the time necessary to develop a project, despite estimates by program managers that projects could be completed in half the remaining time, and by program element monitors that they could be completed in 60 percent of the original time. No follow-up reports address the schedule.

Because of the lack of tools and information, any measure of the required time is difficult to establish with confidence. Nor is it possible to determine which projects are attempting to adhere to an aggressive schedule and which are simply fulfilling an excessively long schedule. Schedules lacking an estimate of required development time would appear to encourage project managers to push for longer-than-necessary timetables to ensure that they can be met.

Observation 3E: The absence of incentives for schedule reduction is partly due to a lack of awareness of the importance of cycle time and its effects on the overall development process. Participants have little knowledge of commercial practices that reduce development time.

The absence of internal incentives appears to stem from a lack of awareness of the effects of long cycle times, and of what can be done to shorten them. Most people involved in the development process want to do what is best for the country, based on their understanding of priorities and options. But because leadership does not emphasize reducing project schedules, other objectives receive more effort. This problem also stems from lack of awareness, education, and training on improvements in commercial development practices. Few people in the defense acquisition system can claim recent experience in commercial product development. Military officers, who make up a majority of the project managers, enter service at a young age and cannot exit and reenter. The few programs that expose acquisition officers to industry activities focus primarily on defense companies, and these hands-on programs are limited and currently being scaled back.

According to a senior faculty member at Defense Systems Management College, courses for project managers teach approved defense policies and practices and not necessarily the best available practices. A review of those courses found few, if any, that relied on commercial examples or experiences.

What's more, few project managers studied product development as part of their formal education. The surveys showed that only 1 in 5 project mangers reported taking a course related to product development at a college or university. Yet, the recent commercial emphasis on reducing product development time has spurred the creation of many university and continuing education programs. These are located primarily at the premier schools, which are not typically available to military officers or government employees owing to the government's unwillingness to pay the high cost of tuition. Very few officers are allowed to attend business schools full time.[111]

Without a common understanding of commercial development practices, managers of defense projects are unlikely to obtain similar results.

4. Overriding Influence of Funding-Related Constraints

As the research shows, the funding process is the dominant influence on development, and on the creation and execution of project schedules. Funding limitations were found to be the overriding cause of long cycle times. Funding issues also consume most of the attention that managers should be devoting to supervising the projects effectively.

The constant focus on the budget process changes the organization's strategic goal from quickly satisfying the user's needs to fighting for money. In this environment, dilemmas associated with product development time appear to be overwhelmed by constant acrimonious budget battles and negotiations. This leads to several funding-related observations.

[111] In 1998, the Air Force has 6 officers attending full-time business schools of which only 1 is attending a top ten rated school.

Observation 4A: Projects are not funded based on the optimum required development schedule.

Budget requests from the Program Offices are based on the level of the funds the offices think they can get, not on what they consider optimal for their projects. Funding considerations are driving project planning to a far greater extent than project planning is driving project funding. The program managers and program element monitors estimated that with full funding and a strong emphasis on short development time, a project could be completed in half the scheduled time.

Observation 4B: There are too many projects in the development process to be efficiently supported by the available resources. This is a key cause of lengthening development schedules.

Across all types of projects from large to small, from and revolutionary to incremental, funding limitations were reported to be the primary factor in determining schedules. Funding limitations were also the most significant barrier to shortening project schedules. These results lead to the observation that the resources available are not adequate to support the projects in development. Simply put, too many projects are competing for too limited resources. The result is that few projects are being completed in an efficient and timely manner. (Similar observations are common among companies with significant problems in their development systems.[112])

This situation is due to several factors. One is that despite a dramatic decrease in the development budget since 1986, the number of projects has not been concomitantly reduced. This has produced a virtual logjam in the development process, lengthening average development time and allowing schedules to slip owing to funding limitations. The result is an increase in the number of projects in development at any one time.

This is not a novel observation for military development projects, and it is not only found during reductions in defense spending. In 1983, during the Reagan era growth in defense spending, the Affordable Acquisition Approach Study found too many projects in the development pipeline to be efficiently supported.[113] The report stated that programs were being squeezed and stretched to accommodate available funding.

Nor is overextending development resources unique to military projects. Most companies with significant problems in their development system face a similar cause. The results are often similar to the military experience as well: long schedules, significant project slip, inefficient

[112] Clark and Wheelwright, Smith and Reinertsen, and others.
[113] The Affordable Acquisition Approach Study. Air Force Systems Command. 1983.

allocation of resources, and products that do not meet changing customer needs. In the commercial marketplace, however, competition provides effective feedback, as other companies with more effective development processes boost their market share and profits, and inefficient firms either improve or go out of business.

Observation 4C: There are few limits on the number of projects in the development process. Any limits that do exist are primarily based on the ability of a Program Office to obtain funding.

Another problem is an inability or unwillingness on the part of Program Offices to limit the number of projects entering or remaining in the development process. The primary consideration in such decisions is whether development plans are adequate and the required funds can be located. As the research showed, project schedules are most often changed to reflect the funding. Because no apparent formal limits exist, significant effort failed to identify the total number of military products in development.

Observation 4D: There is no effective screening process to control the number and types of projects entering development and to ensure that they are optimally planned.

The inability to limit the number of projects results partly from the lack of an effective screening and selection process. Despite the fact that nearly all resources for each mission area are supposed to be allocated through the modernization planning process, 42 percent of all projects surveyed were initiated outside that process by senior leadership. It could not be determined if other projects were canceled or their funding levels were reduced to make room in the budget for these added projects. The reasons so many are initiated outside the formal process may include changing requirements that biannual planning does not account for, a lack of faith in the results, or a lack of discipline in adhering to the results. One very senior former Air Force official expressed displeasure at how the modernization planning process worked and its inability to stay within expected funding allocations, and indicated that the process was turning into a formality rather than a serious exercise.

Decisions as to which projects were begun, continued, or advanced appeared to be spread among various major commands and Pentagon organizations based on the negotiated funding decisions. The decision to advance a project to the next stage did not appear to be based directly on the need for the system or the performance of the project. The process of generating and validating requirements did not appear to effectively limit the number of projects. Hundreds of approved operational requirements documents and mission needs statements exist for unfunded projects. In many cases when senior leadership initiates a project, the project begins before the requirements document is complete. The requirements processes were found to slow the initiation of some projects in specific instances where key leaders doubted the importance of the project, or the project threatened other budget-related priorities. Many of the arguments that occur within the requirements processes appear to be due to their impact on resource allocations, and do not concern operational requirements.

The acquisition milestone decisions as now used do not limit the number of projects initiated or in development. The milestone decisions primarily ensure that a project has met the requirements needed to enter the next phase, and that the funds to support the project *as planned* are allocated within the program objective memorandum (POM). The milestone decision process is not used to determine which projects, which type of projects, or how many projects should be in the development process at any one time. A project almost always passes a milestone decision unless it has obvious technical problems or a significant shortfall between planned and allocated resources. If a significant funding shortfall exists, the project is usually rephased to ensure that the funds and the plan match.

For their part, the major commands establish a preferred order for projects but do not determine the number initiated. Each major command tries to begin as many of its desired projects as possible based on the results of the funding process.

The resource allocation process is the primary method used to limit entry to the development process, but even this process does not effectively control the number of projects. The Pentagon resource allocation process is a multi-level, broad-based, staff-driven process through which participants attempt to gain the “corporate position.” Any such process is more likely to yield compromises and incremental changes than bold decisions, allocating less funding than requested to competing projects. The use of the resource process to select new projects and control entry is undermined by the practice of underestimating a project’s initial cost, and the use of optimistic projected funding levels. Other than the elaborate funding processes, no other central organization or process controls the number of projects initiated.

The fact that the funding process, or any other process, does not limit the number of projects to remain within the number of projects that can be most effectively executed is evident by the number of projects that are funding limited at initiation, and the number that later experience slip owing to funding instability.

Observation 4E: There are no funds available to accelerate projects, and the lack of such funds is a major impediment to shortening project development schedules.

The fact that thousands of desired projects are waiting to be initiated means that 100 percent of development funds are committed to various projects at any one time. Funds that Program Offices do not commit to specific projects may be lost to other offices, the major commands, and other services. Cost overruns and other must-pay bills absorb any additional funds that might have been used to accelerate individual projects. The result is that only a small percentage of projects come in ahead of schedule.

Summary of Observations

These observations, while painting a stark picture of the defense development process, actually provide evidence that the system can significantly improve. Areas in need of attention include schedule-related information and tools, incentives, and the processes for selecting projects and allocating funds. Few of these sectors require changes in law or higher-level regulations, but most do entail changes in organizational emphasis and leadership direction. Implementing the changes will require strong leadership and hard decisions.

The people interviewed are hard-working, well-intentioned, and doing what they believe is in the best interest of the country and their military service. Those people are not the problem. Rather, the process drives them to actions that seem optimal from a project standpoint but that produce less-than-optimal results for the system as a whole.

Summary of Observations

1. Lack of Leadership and Emphasis on Cycle Time

Observation 1A: There has been little leadership on the issue of reducing product development cycle time. Reducing product development schedules is not currently seen as an important priority of the product development system.

Observation 1B: There is currently no visible or widely held goal or objective for cycle time reduction.

Observation 1C: There is currently no strong advocate for cycle time reduction.

2. Schedule Information and Tools in the Development Process

Observations 2A: Schedules are currently based on factors other than the actual time required to develop the project. Once established, these schedules determine the minimum time it will take to develop the project.

Observation 2B: Little rigorous schedule-based information is available to be used to plan, manage, or evaluate the schedules of development projects.

Observation 2C: There are no effective, accepted, or widely used schedule-estimating tools for military development projects. The lack of effective schedule estimating tools limits the ability to make decisions based on the schedule information available.

Observation 2D: Contractors base their proposed schedules on the government's expected schedule and not the analysis of the actual time required for the development phase of the project.

3. Lack of Schedule-Based Incentives

Observation 3A: There are no effective incentives for cycle time reduction at either the Program Office or Pentagon levels.

Observation 3B: There are no effective incentives for cycle time reduction at the contractor level. Schedule incentives in the contracting phase are only to meet the government expected schedule. There are few contract incentives for cycle time reduction during the development phase.

Observation 3C: There are no effective measures or metrics that are used to evaluate the cycle time performance of a project. As such meaningful schedule-based metrics are difficult to establish.

Observation 3D: No use of any measure or estimate comparing the planned or actual development time to the time necessary to develop a project was found.

Observation 3E: The lack of incentive for schedule reduction is in part due to a lack of awareness of the importance of cycle time and its effects on the overall development process or the ability to do anything about it. There is little awareness of the current commercial methods and practices available to reduce development time or of their success in doing so.

4. Overriding Influence of Funding-Related Constraints

Observation 4A: Projects are not funded based on the optimum project development required schedule but based on other funding constraints.

Observation 4B: There are currently too many projects in the development process to be efficiently supported by the available resources. This is a key cause of the lengthening development schedules.

Observation 4C: There are no current limits on the number of projects in the development process. Any current limits that do exist are primarily based on the ability of the project office to obtain funding.

Observation 4D: There is not an effective project screening process to control the number and types of projects entering the development process and to ensure that they are optimally planned.

Observation 4E: There are no funds available to accelerate projects; the lack of such funds is a major impediment to efforts to reduce project development schedules.

Table 13-1: Summary of Observations of the DoD Product Development Process

Chapter 14

Policy Recommendations and Development Strategies

The observations on the overall development process lead to specific recommendations for shortening cycle times for military products. These recommendations are not a complete set of the needed actions but include the necessary first steps toward making the process faster and more effective. A shorter development process will allow for a change in the strategy used to supply warfighters with new and modified systems—one that provides military capability when needed and allows the armed forces to quickly adapt to new technologies and a changing world. Both the specific policy recommendations and the changes in overall development strategy they make possible are discussed in this chapter.

A. Recommendations for Shortening Product Development Time

This research leads to five sets of recommendations that will reduce the programmatic constraints on military product development time. These recommendations address what was found to be the limiting factor in shortening cycle times. They encompass leadership, information, incentives, resources, and demonstrated results.

Overarching recommendations:

1. **Provide clear leadership on reducing cycle time.**
2. **Develop and use schedule-based information.**
3. **Provide incentives for reducing cycle time.**
4. **Mitigate funding-based constraints on development projects.**
5. **Show results through near-term demonstration projects.**

Within each of these areas are specific steps to remove programmatic constraints. The recommendations do not address the organizational and managerial changes contractors and Program Offices need to make, as described in Chapter 4. However, those factors do not appear to be the primary barrier to shorter development cycles. But as programmatic limitations decline, those factors will have to be addressed to further reduce development time. Until then, much needs to be done in areas controlled by government.

The most important recommendation is to adopt a time-driven development strategy, and to make short cycle time an important priority for each project. Today's 10 to 12-year average development time cannot keep pace with technological change or respond to emerging threats, and it raises costs significantly.

The Packard Commission recognized the importance of cycle time when it stated that excessively long development times were the central problem in defense acquisition. The commission's core recommendation was to cut these times in half for major weapon systems. But although the commission's recommendations for reaching this goal were implemented, cycle time did not shrink: the acquisition system did not change from one focused on budget and performance to one concerned with quickly meeting users' needs.

Without this overriding objective, it is this author's view that the system will not change and cannot change. If cycle times do not become a significant focus they will likely continue to grow and the defense development process will remain ineffective and inefficient.

Making the decision to change the major focus of development is not easy, nor will such a change likely happen quickly. Significant obstacles must be overcome. Below are specific recommendations to begin the process of overcoming those barriers. (For additional information on the research supporting these recommendations and their implications, see Appendix 1.)

Recommendation 1: Provide clear leadership on reducing development cycle time.

Reorienting organizations to accept schedule as an important factor and shorter cycle times as an important objective will require significant leadership at all levels. Leaders will have to show that shortening development time relates directly to the ability to provide an effective and affordable defense. Leaders will also have to set aggressive goals for reducing cycle times and remain strong and powerful advocates for them, holding organizations accountable for meeting the goals.

Recommendation 1.1: Make a clear business case for reducing development cycle time.

Recommendation 1.2: Establish quantifiable goals for reducing development cycle times.

Recommendation 1.3: Appoint an advocate for reducing development cycle time.

Recommendation 2: Develop and use rigorous schedule-based information and tools.

Accurate information and analysis are required to make informed decisions on project schedules. Today schedules are primarily based on expected funding levels and not on rigorous evaluation partly because of a lack of available and easy-to-use tools. Three steps could help address that need. First, a formal estimate of development time, and an analysis of the factors limiting schedule, must be part of the project approval process. This could take the form of a "should take" analysis--similar to the "should cost" estimate of how much a project would cost if done as efficiently as possible. Such an analysis would rely on a comparison with other projects, parametric estimation of the required time, and a bottom-up estimate stemming from engineering requirements. This analysis would provide senior leaders with the information they need to make informed scheduling decisions and allow them to establish realistic project goals. Such an analysis would also highlight the barriers to shortening project schedules early in a project's planning phase. Similar analysis should be included by the contractors when presenting their proposed schedules.

Recommendation 2.1: Base initial project plans on development-related requirements and perform a "should take" analysis.

Recommendation 2.2: Develop and use effective tools for estimating and evaluating project schedules.

Recommendation 2.3: Require contractors to include a "schedule proposal" section in their overall proposals.

Recommendation 3: Provide incentives that encourage shorter cycle times.

Some negative schedule-related incentives may change when leaders place a greater emphasis on shortening project schedules and explain their rationale. But even with such leadership, strong disincentives to reducing cycle time will have to be consciously removed and significant positive incentives established for the Pentagon, Program Office and defense contractors before significant changes can occur.

Incentives for contractors can be applied both before and after the contract award. Making the length and risk of the proposed schedule a significant criterion for winning a contract will encourage companies to set schedules that are both short and achievable. Then, incentives in the contract itself can encourage contractors to achieve the planned schedule and further shorten it. Contracts should also include penalties for failure to achieve the specified schedule.

A significant training program must be established to convince the defense acquisition community, including contractors, that shortening cycle time is important, that it is possible, and that the commercial sector has done so through a variety of means that can be emulated. Such an effort will require an awareness of the best product development practices from a wide array of industries.

Recommendation 3.1: Provide incentives at the Program Office and Pentagon levels.

Recommendation 3.2: Provide incentives at the contractor level.

Recommendation 3.2.1: Make the length of the development schedule and the associated risk a significant criterion in contractor selection.

Recommendation 3.2.2: Provide significant schedule-based contract incentives.

Recommendation 3.3: Provide extensive training on best product development practices from commercial industry.

Recommendation 4: Mitigate funding-based schedule limitations.

The foregoing recommendations are unlikely to have a noticeable impact without significant changes in the method by which the services and DoD fund development projects. To create products efficiently and effectively, projects must be funded at the levels determined by their development-related requirements. And each should be funded according to its most effective and efficient schedule. These changes will require controlling the number of projects under way at any one time.

All these goals can be achieved by establishing a formal screening process to determine which projects are highest priority and which can be fully funded within the available resources and the planned time. A multiple-level screening process would also allow projects to compete for approval to proceed to the next development phase.

To ensure sufficient funding to fully support each project, the number of projects within each phase at any given time should be limited. This limit could be reached by completing many projects more quickly while delaying, postponing, or canceling others.

Once a project is in the development process, it is important to ensure that it can move through it as quickly as possible. To make that possible, funds for accelerating the schedule as opportunities arise must be readily available. Priority in the use of funds that become available must be given to accelerating and completing existing projects rather than to initiating new ones.

Recommendation 4.1: Require that all projects initiated be fully funded based on development-related requirements.

Recommendation 4.2: Establish an effective project screening process.

Recommendation 4.3: Limit the number of projects in each phase of development.

Recommendation 4.4: Clear the logjam of current projects.

Recommendation 4.5: Ensure that resources are available to accelerate projects as opportunities arise.

Recommendation 5: Show results through near-term demonstration projects.

Since DoD has little experience in reducing cycle times, and lessons from the commercial sector are not always directly applicable, demonstrations can help verify the impact of the aforementioned changes.

The effect of many recommendations, including enhancing the incentives for reducing development time, can be observed by selecting individual projects as demonstration vehicles. The impact of other recommendations, such as establishing a screening process, can be seen only when applied to a portfolio of projects. In that case, a Program Office that oversees a large number of smaller projects can be selected as a "reinvention laboratory" and given wide leeway to implement the recommended changes. While this would require significant coordination and high-level support, it could demonstrate the cumulative and interactive effects of the recommendations across an entire development organization. Such a result would give DoD confidence to adopt the recommendations across all weapon systems.

Once the ability to produce products quickly, effectively, and reliably is demonstrated, significant other changes can occur in the strategy used to develop weapons.

Recommendation 5.1: Establish pathfinder projects that demonstrate the effectiveness of the cycle time reduction approach.

Recommendation 5.2: Establish a reinvention laboratory that demonstrates the effectiveness of the approach on products within an entire Program Office or Product Center.

Table 13-1

Summary of Recommended Actions to Reduce Development Time for Defense Products

Recommendation 1: Provide Clear Leadership on Reducing Cycle Time

1.1 Make a Clear Business Case for Reducing Cycle Time

1.2 Establish Quantifiable Goals for Reducing Cycle Time

1.3 Appoint an Advocate for Reducing Cycle Time

Recommendation 2: Develop and Use Rigorous Schedule-Based Information and Tools

2.1 Base Initial Project Plans on Development-Related Requirements and Perform a "Should Take" Analysis

2.2 Develop and Use Effective Tools Estimating and Evaluating Project Schedules

2.3 Require a "Schedule Proposal" Section in Contractor Proposals

Recommendation 3: Provide Incentives That Encourage Cuts in Cycle Time

3.1 Provide Incentives at the Program Office and Pentagon Levels

3.2 Provide Incentives at the Contractor Level

- 3.2.1 Make the Length of the Development Schedule and Associated Risk Significant Criteria in Contractor Selection
- 3.2.2 Provide Significant Schedule-Based Contract Incentives

3.3 Provide Extensive Training on Best Development Practices

Recommendation 4: Mitigate Funding-Based Schedule Limitations

4.1 Require All Projects to Be Fully Funded Based on Development-Related Requirements

4.2 Establish an Effective Project Screening Process

4.3 Limit the Number of Projects in Each Phase of Development

4.4 Clear the Logjam of Current Projects

4.5 Ensure That Resources Are Available to Accelerate Projects as Opportunities Arise

Recommendation 5: Show Results through Near-Term Demonstration Projects

5.1 Establish Pathfinder Projects That Demonstrate the Effectiveness of the Approach to Reducing Cycle Time

5.2 Establish Reinvention Laboratories That Demonstrate the Results within an Entire Program Office or Product Center

B. Longer-Term Recommendations for Changing the Development Strategy

Shortening the time required to develop weapon systems is important in developing better systems faster and at lower cost. However, it also represents a key step in allowing a larger change in the way military systems are developed and fielded. A fast development process will provide the U.S. with a long-term, sustainable military capability to respond quickly to changing threats and emerging technologies. A shift in strategy from developing a wide array of systems to cover all possible emerging threats to one that is more responsive to specific threats will ensure that the right weapons are developed and ready to be fielded at the right time.

The military worth of a system is based on two inherent aspects. The first is its performance advantage over an opposing system. The second, often not fully considered, is the length of time that system can retain its technical advantage and avoid compromise by countermeasures. To head off such compromise, the services usually call for significant technological superiority in a broad range of areas to ensure dominance even if an enemy finds a way to counter a specific system. Thus, the U.S. Air Force now builds systems "just-in-case"--as insurance against a "pop-up" threat. This is one argument for the F-22 and Joint Strike Fighter, both intended to counter threats that may develop over the next 30 years.

The net effect is that many systems are developed to meet threats that never materialize, and when systems are finally fielded they face a dramatically different mission than they were designed for. While Pentagon respondents indicated that 70 percent of projects were designed to meet current operational deficiencies, they indicated that fully 30 percent were intended to meet projected needs that may not materialize. This leads to the worst type of inefficiency—developing and producing the wrong weapon at the wrong time with obsolete technology. The B-2 and MILSTAR systems are visible examples of systems designed to meet a mission that never materialized or that disappeared before the systems were completed. Such systems are then pushed into a service for which they were not designed and may be ill suited. A specific example is using the MILSTAR as a tactical communications terminal instead of as a strategic system during the second stage of a nuclear exchange.

The just-in-case strategy forces the U.S. to spread its resources over many systems, a practice that results in longer development times. Revamping the basic strategy from just-in-case to just-in-time requires two changes. First, the U.S. must be able to develop new systems quickly, and second, it must be able to produce enough units rapidly.

The U.S. now takes 10 to 20 years to develop and field major weapon systems. These systems are expected to be in operation for 20 to 25 years. That forces the country to project threats and military and commercial technologies 40 years into the future—an impossible task. Such an unrealistic goal is what drives the demanding performance requirements—and the resulting high costs--of military systems.

The recent response to long cycle times has been to establish a long-term planning organization in the Pentagon to project required force structure, weapons, and technologies 25 to 40 years in advance. The effect of these plans is to lock in systems and related schedules long before it is possible to know the actual threats. Once made these plans and schedules prove very difficult and costly to change.

The system is most closely comparable to the central planning function of Communist countries with few market or entrepreneurial forces at work. Bureaucratic processes dominate planning and the results are long development schedules and too many projects in development. The system also forces developers to make large technological leaps to ensure that systems are technically superior when they are eventually fielded—further exacerbating the problems. A just-in-time strategy would allow a more targeted approach in deciding which systems are needed to counter real threats. It would also reduce U.S. vulnerability to unpredicted enemy systems based on new technologies or novel combinations of existing technologies.

A just-in-time approach would not be new--it was the traditional U.S. military strategy from the Revolution through the Second World War. Only during the Cold War did the U.S. feel the need to maintain long-term technological superiority over all enemies. During World War II, the U.S. developed better systems quickly and produced them massively. But the speed and potential effects of nuclear war and our unpreparedness for the Korean War made the U.S. fear being caught unprepared. This developed into the idea of the "come as you are" war, which would be fought in Europe, with the ultimate winner determined in a matter of weeks before any production could affect the outcome. I believe the chance of this type of total lightning war has been thoroughly eliminated by the changes in Russia and the lessening of the perceived nuclear threat. Smaller operations will still be on a "come as you are" basis but will require only significant—as opposed to massive--inventories of the highest-technology weapons.

A fast development strategy would rely on critical technologies and subsystem components that are developed to the point where they can be assembled quickly, tested, and then produced as needed en masse. Such key technologies would be in the areas of sensors, signal and computer processors, communication systems, warheads, autonomous control, and navigation. A "develop and test but not produce" strategy would keep the U.S. aerospace industry's product development capability in shape to ensure that it could be called upon when needed. Such a strategy would allow for continual design improvements without the cost of actually implementing the modifications. This strategy is similar to the design, build, and test policies, known as Silver Bullet, that surfaced during the early 1990s. But those policies were proposed more because of a lack of production money rather than a shift in overall military development strategy. The Silver

Bullet strategy was not widely accepted for a variety of political reasons, which may have changed since the end of the Cold War and the move toward lower defense budgets.

The central enabling aspect of a just-in-time strategy would be reliance on a "civil reserve industrial capacity," much as the Air Force relies on the Civil Reserve Air Fleet to augment its transport aircraft with commercial aircraft. This requires that military and commercial production capacities be merged. Such a merger is the major goal of Dr. Kaminski's, the former Defense Acquisition Executive, efforts to remove military specifications and production standards in favor of single commercial standards and processes.[114] This strategy would allow the U.S. to maintain defense capacity for times of emergency without incurring the cost of constantly producing defense products that we do not need at the present time. The strategy also allows a move away from the need for constant care and feeding of the defense industrial complex. The DoD would pay commercial manufacturers to maintain the ability to shift rapidly to production of military systems.

But before that can happen, the defense industry must become lean enough to compete in the commercial market, or commercial firms must be allowed to compete in the defense market without large barriers. If one reads many of the Defense Science Board studies led by Dr. William Perry at the height of military spending in the late 1980s, one sees a merger of defense and commercial industry as a central theme for this very reason.[115] Such a merger is starting to occur in the satellite, electronics, and engine industries, but has not yet occurred in the aircraft or munitions areas.

Both political and technological reasons make a change from just-in-case to just-in-time strategy not only desirable but also possible today as opposed to 10 years ago. Key military technologies are now drawn primarily from the commercial sector, which moves faster than military efforts. Also, open architectures for commercial computer systems are being used in military systems, the quality of commercial products often exceeds military standards, and a policy of replacing rather than repairing military components reduces maintenance concerns.

Political changes include reduction of the military threat and a period of clear military superiority, which provides time to reorganize without risk. Changes also include acceptance of substantially lower long-term defense budgets, the diminished threat of global war and a focus on regional conflicts, and the recognition by industry and military leaders that things can and must change if we are to provide effective weapons over a longer period.

[114] Statement of the Under Secretary of Defense for Acquisition and Technology, Paul G. Kaminski, before the Subcommittee on Defense Technology, Acquisition and Industrial Base of the Senate Committee on Armed Services on Dual Use Technology. May 17, 1995.

The demonstrated capability to quickly develop and produce weapons is the key factor enabling such changes to occur. I propose that the long and difficult process required to shorten development cycle times and increase the effectiveness of our development system begin now, based on these recommendations.

[115] Use of Commercial Components in Military Equipment. Final Report of the Defense Science Board 1986 Summer Study. January 1987. Office of the Under Secretary of Defense for Acquisition.

Appendices

Additional Supporting Information

Appendix 1

Proposed Policy Recommendations

The recommendations have been updated from the original dissertation to include suggested implementation strategies. RTM

Policy Recommendations to Reduce Air Force Product Development Times

Major Ross McNutt, Ph.D.
Secretary of the Air Force (Acquisition)
Acquisition Management Policy

mcnuttr@alum.mit.edu

Overarching Recommendations

1. **Provide clear leadership for cycle time reduction**
2. **Develop and use schedule-based information**
3. **Provide incentives for cycle time reduction**
4. **Mitigate funding-based constraints on development projects**
5. **Demonstrate application and results through near term demonstration projects**

Recommendation 1: Provide Clear Leadership on Cycle Time Reduction

Recommended Actions

1.1 Make a clear business case or rational for cycle time reduction (macro case and project-by-project)

1.2 Establish clear quantifiable cycle time reduction goals

1.3 Establish functional advocate for cycle time reduction

1. Provide Clear Leadership on Cycle Time Reduction

Research findings

- No consensus of the importance or effects of long cycle times or reduction of cycle times
  - Fourth of 4 in priority at all levels
- No accepted goals of cycle time reduction
  - Current goal is to meet schedules not reduce them
- No organization assigned responsibility for cycle times
  - FM budget focused
  - Users performance/budget focused
  - AQ budget/performance/technology/new system focused

Recommendation 1.1:
Make Clear Business Case for Cycle Time Reduction

Research Results - **No clear or widely accepted understanding of importance or impact of shortening development cycle time**

- **Short Schedules rated last in priority**
- **Widely disparate views encountered across all organizations**

Recommended Action - **Develop a clear case for cycle time reduction**

- **Identify both positive and negative impact and effects of reducing cycle time**
- **Must be based on detailed and rigorous analysis of the entire development cycle**
- **Identify the effects of cycle time on each community in their own language and based on their concerns**
  - **The Warfighter, Budget, Acquisition, and Contractor Community**
  - **On individual project, weapon systems, and the acquisition system as a whole**

Suggested Implementation Strategy - **Direct a task force with representation from all key organizations to develop and present the business case for cycle time reduction**

- **Encourage them to get independent assistance on current commercial experience**
- **Recommend being done under auspices of exiting OSD(A&T), AF Cycle Time Teams**
- **Once completed case must be widely presented by senior leadership across all organizations.**

Major McNutt mcnuttr@af.pentagon.mil 4/13/99 cycletime5 ©1999 Ross McNutt

Recommendation 1.2:
Establish Clear Cycle Time Reduction Goals

Research Results

- **No widespread or accepted goal for cycle time reduction across all organizations**
- **Current acquisition community goals based on cost and performance issues**
- **Schedule goals are to meet current schedules which are largely based on budget**

Recommended Action - **Establish clear service and DoD-wide goal for the reduction in the time from project initiation to delivery of the first production item for each category and type of project**

- **Establish current baseline for current cycle time**
- **Recommend average reduction goal of 50% from project initiation to first production item**
- **Categorize by size and system type**
- **Recommended Time to achieve goals - ACAT III - 3yrs ACAT II - 5 yrs**
- **Establish ongoing schedule metrics and tracking system for all projects**

Suggested Implementation Strategy - **Have Secretary of Defense and Service Secretaries establish goals that apply across all organizations and services**

- **Suggest existing task force or a specified organization develop measurable goals and metrics for cycle time reduction based on categories of systems**
- **Develop systematic survey of all project to measure progress to goal**
- **Assign responsibility for meeting goals to OSD(A&T) and Service Acquisition executives**

Major McNutt mcnuttr@af.pentagon.mil 4/13/99 cycletime6 ©1999 Ross McNutt

Recommendation 1.3: *Assign Responsibility for Cycle Time Reduction To the Acquisition Community*

Research Results

- **No organization was found to have or to have assumed responsibility for cycle time or cycle time reduction**
- **Cycle time issue appears to be submerged in budget process**

Recommended Action - **Acquisition organizations should embrace cycle time reduction as a major organizational goal**

- **Use organizational and legal authority to push cycle time as an issue**
- **Use milestone authority to enforce changes**
- **Acquisition community must develop tools and practices to address cycle time issues.**
- **Acquisition community must adopt to become a culture to allow fast cycle times**

Suggested Implementation Strategy - **Secretary of Defense and Service Secretaries should formally assign primary responsibility for cycle time reduction to the acquisition organizations**

- **Establish and staff an office to assist the leadership in managing the schedule reduction effort by tracking and maintaining schedule based metrics, tools, and policies within the acquisition organizations**

Major McNutt mcnuttr@af.pentagon.mil 4/13/99 cycletime7 ©1999 Ross McNutt

Recommendation 2
Develop and Use Rigorous Schedule-Based Information and Tools

- **2.1** **Develop Initial Project Plans on the Development Related Requirements**
- **2.2** **Develop and Use Effective Project Schedule Estimation and Evaluation Tools**
- **2.3** **Require "Schedule Proposal" Section in Contractor Proposals**

Major McNutt mcnuttr@af.pentagon.mil 4/13/99 cycletime8 ©1999 Ross McNutt

2. Develop and Use Schedule Based Information

Research findings:

– Little detailed schedule based-information available or used to make decisions
– No scheduling tool was found to be available or widely used
– Contractors use customer's expected schedule to develop their proposals
– Schedule information difficult to evaluate

Recommendation 2.1: Develop Initial Project Schedules Based on Development Related Requirements

Research Findings

– Project schedules are primarily developed based on expected funding availability
– There is little rigor in development of initial schedules
– Initial project schedules have a major impact on eventual schedule as they essentially determines minimum schedule

Recommended Action - Require a detailed analysis of required schedule and require it be documented in a project "Should Take"

– Require all new project plans be based on the estimated time required to develop the product based on its development requirements (with an appropriate amount of schedule reserve and risk (Right Scheduling)).
– Provide the programming process real data instead of "gamed" or manipulated schedules that attempt to anticipate "realities" of programming constraints.
– Required detailed proposed schedules for all new projects be fully justified and documented as part of a Milestone Decision
– Milestone Decision Authorities must enforce quality
  - OSD(A&T) ACAT ID, SAE ACAT IC and II, and DAC ACAT III
– Structure must be compatible with requirements for future schedule estimation tools

Suggested Implementation Actions

– OSD(A&T) direct inclusion of Project "Should Take" Analysis as a requirement in DoD 5000 regulation for ACAT I and SAE direct its use at the lower levels.

Proposed Content of the Project "Should Take" Analysis

- Results of different analysis methods used to evaluate required schedule
  - Bottoms-up schedule development, parametric estimation, analysis of comparable DoD projects, analysis of comparable commercial projects, contractor estimates
  - Discussion of analysis and its limitations and applicability to this project
- Program office's estimate of time required to develop project as proposed
- Analysis of users schedule-based requirements
  - When do they need it, when do they want it, and the reasons why
  - Mission and cost impact of not having it by quarter/year (Cost of Delay Analysis)
- Identify current schedule limiting and risk factors
  - Schedule sensitivity analysis of requirements and other factors
  - Resource loading/availability
- Detailed Program Office proposed schedules

  (Minimum projected possible, realistic goals, and maximum allowed)
  - Proposed project initiation date
  - Detailed proposed project schedule
  - Identify logical decision points and key milestones
  - Identify critical and near-critical path Items
  - Schedule risk analysis and sensitivity
- Schedule management issues
  - Project schedule goals, objectives, and requirements
  - Schedule monitoring system, metrics, and incentives to be used at each level

Major McNutt mcnuttr@af.pentagon.mil 4/13/99 cycletime11 ©1999 Ross McNutt

Current Required Milestone I Documentation

- Acquisition Strategy Report
- Acquisition Program Baseline
- Affordability Assessment
- FYDP Funding Profile
- Analysis of Alternatives
- Component Cost Analysis
- Cost Analysis Requirements Description
- Description of Data Requirements
- Exit Criteria
- Independent Estimate of Life Cycle Cost
- Operational Requirements Document
- Program Office Life Cycle Costs Estimate
- System Threat Assessment Report
- Test and Evaluation Master Plan

None Address the Development or Analysis of the Project Schedule Directly

Major McNutt mcnuttr@af.pentagon.mil 4/13/99 cycletime12 ©1999 Ross McNutt

Recommendation 2.2: Develop Effective Project Schedule Development and Evaluation Tools

Research Findings - **No effective schedule estimation tools or schedule-related databases are readily available or used by the program offices or contractors**

Recommended Action - **Develop and use a comprehensive database of project schedule information and schedule estimation tools**

- **Collect all current project schedules at a level detailed enough for sub-unit comparison**
- **Use a detailed and recurring schedule based surveys of all ongoing projects**
- **Augment with commercial product development databases and experiences**
- **Develop detailed schedule guidelines, benchmarks, parametric models to be used to project estimate schedules**
- **Organize in easy to use computer based tool that allow easy use and schedule estimation**
- **Develop advanced schedule estimation and risk analysis tools using methods such as the Design Structure Matrix**
- **Make resulting data and tools readily available to all organizations**

Suggested Implementation Method

- **OSD(A&T) or SAEs hire a respected company (Rand, TASC, IDA, Supplement or expanded effort of LAI) to collect, assemble, and organize required schedule based data.**
- **Collect required information through detailed and recurring surveys of existing project. They also would develop a wide arrays of benchmarks.**
- **Maintain schedule models as separate and distinct but compatible with existing cost models.**
- **Maintain control of schedule models within the acquisition community.**

Recommendation 2.3: Require a "Schedule Proposal" Section in the Contractors Proposal

Research Findings

- **Contractor's primary schedule input is customer's expected schedule**
- **Schedule based information is currently spread across different proposal sections**
- **Information needed to effectively evaluate schedule based information**

Recommended Actions - **Require separate "Schedule Proposal" in addition to cost and technical proposals**

- **Envisioned similar to Program Offices "Should Take Analysis"**
- **Contractors propose detailed schedule, start date, analysis, and associated projected risks**
- **All critical and near critical paths identified, and discussion of schedule limiting factors**
- **Company demonstrated schedule capability and past performance (Company Comps)**
- **Company's requested schedule based incentives structure**
- **Proposed methods to manage, measure, and establish incentives to reduce schedule**
- **Structured to allow consistent and effective schedule based evaluation and the associated risk from all companies using tools to be developed**

Suggested Implementation Strategy

- **Organize a group from the three services and Defense industry associations to establish the appropriate information and structure to be included in the schedule proposal section for different size and types of projects.**
- **Direct requirement for "Schedule Proposal" to be included in all future RFPs and proposals.**

Recommendation 3
Provide Incentives That Encourage Cycle Time Reduction

3.1 Provide incentives for cycle time reduction at the Program Office level

3.2 Provide incentives at the contractor level

3.2.1 Make the length of the development schedule and the associated risk a significant source selection criteria

3.2.2 Provide significant schedule-based contract incentives to meet and reduce the schedule

3.3 Provide extensive training on best product development practices in all industries

3. Provide and Align Incentives For Cycle Time Reduction

Research Findings:

- **No incentive reported by any level -- Pentagon, Program office, or contractor -- to reduce development cycle time**
- **Shortened schedule last of 4 project objectives**
- **Many projects completed exactly on schedule**
- **Very few projects ever completed ahead of schedule**
- **Schedule is first to be sacrificed**

3.1 Provide Incentives to Reduce Cycle Time to Program Office

Research Findings

- **Many project managers per project (3.7 average) - Current avg. time 15 months**
- **Little personal accountability or feeling of responsibility for schedule observed**
- **Shortening schedule seen as lowest priority**

Recommended Actions: Develop a set of organizational and personal incentives for program offices for cycle time reduction

- **Develop and track schedule-based metrics for all projects to track schedule performance**
- **Increase program office and project manager schedule accountability**
  - **Assign project and program managers to the projects for 3 years minimum**
- **Use schedule length and schedule performance measures as a significant performance metric for program office and personal performance ratings**
- **Make project cycle time and cycle time reduction a significant part of program office and personal award programs**
- **Use development time as a significant factor in the project screening to select which projects progress to the next phase**

Suggested Implementation Strategy **- SAE's direct a team to develop specific recommendations for providing effective and broad based incentives to shorten cycle time at the program office level.**

Recommendation 3.2.1 Make Development Schedule and Schedule Risk a Significant Source Selection Criteria

Research Findings**:**

- **Contractors report no incentive to reduce cycle timer to bid a shorter project schedule**
- **Very few contractors propose schedules other than government expected schedule**
- **Government expected schedule primary schedule input**
- **Schedule is not seen as important development criteria**

Recommended Action: **Makes development time and the associated schedule risk a significant source selection criteria**

- **Establish effective schedule-based source selection criteria**
- **Use previously proposed schedule proposal as basis for evaluation**
- **Develop effective and accepted schedule evaluation procedures**
- **Use development time as a significant criterion at each stage of the project screening process**
- **Combine with significant schedule-based incentives meet or shorten schedules**

Suggested Implementation Strategy

- **OSD and SAE establish team of government and contractor representatives to establish framework and standard menu of acceptable options that may be used to evaluate and weight schedules and schedule risk as a source selection criteria on a specific development project**
- **Methods used to be selected by program offices following consultation with industry**

Recommendation3.2.2: Provide Significant Contract Incentives for the Reduction of Development Schedules

Research Findings

- **Contractors report little or no incentive to accelerate contract schedules**
- **Program offices report no contract incentives for schedule performance or schedule reduction**

Recommended Actions: **Provide significant schedule based incentives to the contractor to meet and also reduce project schedules in the development phase**

- **Develop a framework from which to base and evaluate schedule based contract incentives**
- **Develop an accepted and standardized menu of options for schedule based incentives which are acceptable and for which the implications are understood by both government and contractors communities**
- **Incentive structures must encourage both meting and reducing the current planned schedules.**
- **Incentives must be structured so that they do not undermine other goals of the project**

Suggested Implementation Strategy

- **OSD and SAE direct a integrated government and industry team to develop a framework for and options included in a menu of accepted schedule-based contract incentives**
- **Request contractors propose the specific incentives structure and levels that they would like as part of their schedule proposal**
- **Allow the government to consider the effect of the schedule-based incentives as part of the evaluation of the proposals and their risk**

Recommendation 3.3: Provide an extensive training program on best product development practices

Research Results**:**

- **Little widespread awareness of best product development practices from other industries**
- **Only 1 of 5 project managers report taken a formal product development course**
- **Government acquisition courses teach current DoD policy and do not teach best product development practices as seen throughout other and related industries**

Recommended Action: Start and comprehensive multifaceted training program to educate acquisition personnel and others involved in the development process the current best product development practices from a wide variety of industries

- **Individual Training - Establish a reading program with regular SPO level discussion groups.**
- **SPO and Center Level Training - Establish recurring seminars on best product development practices with speakers from variety of industries - Use Commercial Prod Dev Consultants**
- **Formal Training - Establish lessons in current training programs on best product development practices based on other industries experience - Bring in Comm Product Dev Consultants**
- **Formal Education -Establish a formal competitive scholarship program for officers to attend top level academic institutions to study best product development practices -- Rec 50 per year**

Suggested Implementation Method

- **OSD(A&T) and SAE direct DSMC or another group to develop and implement a comprehensive multifaceted training program on for those involved on the development process of the best product development practices from all industries.**

Recommendation 4. Mitigate Funding-Based Schedule Limitations

4.1 Require all projects that are initiated be fully funded based on development related requirements
4.2 Establish an effective project screening process
4.3 Limit the number of projects in each phase of development
4.4 Clear logjam of current projects
4.5 Ensure necessary resources are available to accelerate projects as opportunities arise

4. Mitigate Funding-Based Constraints

Research Findings:

- 80% of projects' schedules reported to be funding constrained not technically constrained
- Estimated time required to completion averages 50% of current planned time to completion
- Most initial project plans based on funding constraints, not technical requirements
- Inability to locate funding cited as most important barrier to cycle time reduction

Recommendation 4.1: Require That Projects to be Initiated Must Be Fully Funded Based on Development-Related Requirements

Current Situation -

- 80% of project schedules are limited by funding and not limited by technical development aspects.
- Current practice requires that the project be "fully funded" "as planned"
- Project Plans were shown not to be based on the development requirements.

Recommended Action

- Require project funding profiles and schedules be established based on the optimal time required to develop the project
  - Develop optimal schedule -- then allocate funds required through PPBS process to carry out project
- Use project screening process and Milestone Decision Authority to limit projects entering the development process to those that can be optimally funded
- Rescind approval from projects that funding profiles are significantly altered after a milestone decision

Suggested Implementation Strategy

- OSD(A&T) and SAE direct all plans to be developed based on project requirements and then following a project screening process input projects into the PPBS process
- Initiate with ACAT II and III projects and demonstrated effects prior to implementation with ACAT I projects

Major McNutt mcnuttr@af.pentagon.mil 4/13/99 cycletime23 ©1999 Ross McNutt

Recommendation 4.2: Establish an Effective Project Screening Process for Entry into Each Phase of Development Process

Current Situation

- No effective process used to select or control projects entering into each phase of development
- Current limiting process primarily based on ability to locate funds to initiate project
- Milestone decision process not effectively limiting projects, especially small projects

Recommended Actions - Establish a competitive project screening process to allow the highest priority projects that are fully ready and can be supported by the available resources to enter each phase of development

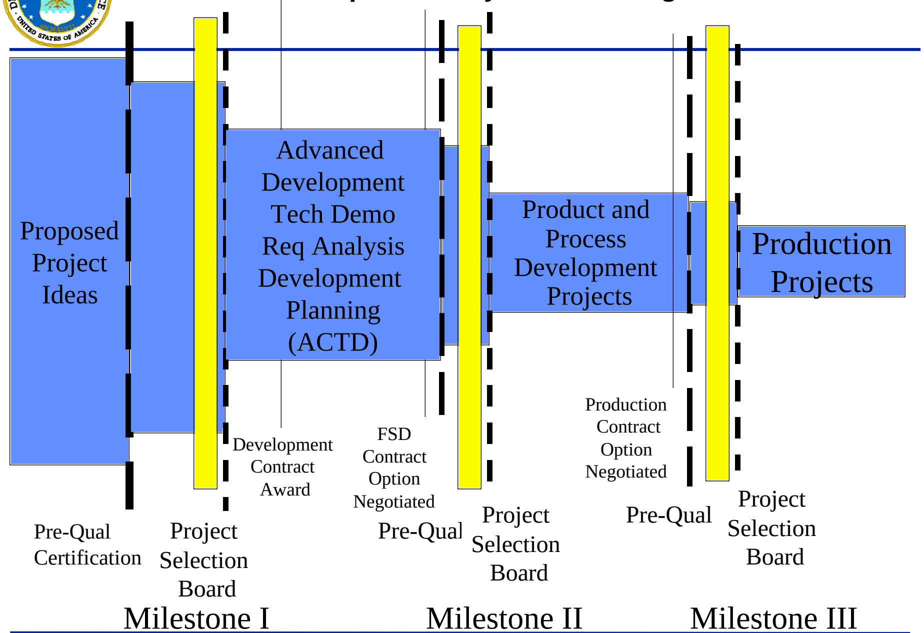
- Select the projects that will be allowed to proceed to the next development phase, those that will remain in the current phase, and those that will be canceled.
- Senior leaders to run a "Project Evaluation and Selection Board"
  - Direct project to project comparisons -- Similar to Office Promotion Board
- Selection categories done by mission area and ACAT level or some other logical grouping
- Require all projects to pass through the process (allow only emergency exceptions)
- Require Pre-certification evaluations from each community on each project prior to board
  - Users -- military worth; AQ -- adequacy of dev plans, schedule, risk; FM -- Cost Estimates
- Use results of selection process as direct input into PPBS process.
  - Control dollar amount by number of projects

Suggested Implementation Strategies

- OSD(A&T) and SAE or higher direct the establishment of a project selection process to select projects that will enter into each phase. Demonstrate process effectiveness with ACAT III projects first then migrate to ACAT II and then ACAT I projects once demonstrated and established

Major McNutt mcnuttr@af.pentagon.mil 4/13/99 cycletime24 ©1999 Ross McNutt

Proposed Project Screening Process Structure



Major McNutt mcnuttr@af.pentagon.mil 4/13/99 cycletime25 ©1999 Ross McNutt

Pre-qualification Certification and Ratings

- **Pre-qualification states that, if approved, the project stands a very high probability of completing within its cost, schedule and performance requirements and that it will meet the operational mission that it is intended**
- **Pre-qualification certifications -- ensure that the estimates in each area are accurate as stated and level of risk identified**
  - **Projected cost - FM responsibility**
  - **Operational - Users responsibility**
  - **Schedule- AQ responsibility**
  - **Management plan - AQ responsibility**
  - **Technology proven - AQ responsibility**
  - **Contract options signed and ready (Milestone II and III)**
- **Pre-qualification certification and ratings would be obtained from the respective organizations prior to the Project Selection Board. No project would be allowed to meet the selection board without them.**

Major McNutt mcnuttr@af.pentagon.mil 4/13/99 cycletime26 ©1999 Ross McNutt

Project Selection Board

- Formed by senior service, unified command, MAJCOM leaders or their deputies
- Would do a project-by-project comparison within certain categories
  - Project areas separated by size and possibly mission areas
- Projects would be rank ordered based on information presented within each area
- Senior leaders would select projects based on criteria that would be based on budget allocation
- Final selection made by Service and DoD leadership
- Have option of returning projects to current phase, completing and documenting or selecting it for the next phase

Major McNutt mcnuttr@af.pentagon.mil 4/13/99 cycletime27 ©1999 Ross McNutt

Recommendation 4.3: Limit the Number of Projects in Each Phase of Development

Research Findings
- No established or effective limit to the number of projects in the development phase
- No effective control method - ability to obtain and maintain funding - only current limit
- Little control over smaller projects - too many projects to oversee even at program office

Recommended Action - **Establish firm limits on the number of projects allowed in each phase of development at any one time**
- Decreasing number of projects per phase
- Force selection boards and leaders to make hard decisions between projects
- Encourage to push projects through the development process or stop them
- Establish limits based on the amount of projected funding with management reserve
- Should specify mix of size, projects, weapon system types
- Allow trades small vs large projects with an appropriate weighting (i.e. 7 small to 1 large)
- Allocate number of projects prior to selection board with opportunity to revisit following

Suggested Implementation Strategy
- OSD(A&T) and the Service Acquisition Executives, with concurrence of the Defense and Service Secretaries should specify the total number of project that may be in each phase of the development process at once. Strictly enforce through use of Milestone Decision Authority.

Major McNutt mcnuttr@af.pentagon.mil 4/13/99 cycletime28 ©1999 Ross McNutt

Recommendation 4.4: Clear Logjam of Current Projects

Current Situation**:**

- Logjam of current projects in development is causing large amount of project slip
- Funding Instability accounting for half of project slips
- Large number of projects in development but the actual number is unknown
- Recent large reduction in available development funds -- few project cancellations

Recommended Actions -

- First identify and document all current development projects at the project level
  - Categorize into project types and phases for project screening process
- Use proposed project screening process to review and prioritize all current projects
  - Identify the lowest-priority projects and stop them -- use resources to accelerate others
- Time phase remaining development projects to conduct them in series not parallel
  - By contractor facility and program office, pair ongoing development projects
  - Place one project on hold and use its resources and personnel to accelerate the other
  - When first project is nearing completion, restart project on hold.

Suggested Implementation Steps

- SAE direct several demonstration projects to show results on smaller projects
- OSD(A&T) and Service Acquisition Executives then negotiate with Industry CEOs to obtain agreement on wide spread implementation of concept. Direct implementation at the PEO and Product Center Level

Recommendation 4.5: Ensure that Necessary Resources Are Available to Accelerate Projects Schedules

Research Findings:

- Lack of available funds reason most cited for not accelerating projects
- Very few projects ever accelerated
- Project managers estimate projects could be done in half the remaining time

Recommended Action: **Establish a management reserve to be used for cycle time reduction -- Use annual fallout money to accelerate projects first**

- Give cycle time reduction requests first priority at any extra available funds
- Earmark fallout funds for cycle time reduction efforts only
- Disallow use of fallout money for new starts or additional requirements (New starts controlled by project selection process only)

Suggested Implementation Strategy

- OSD(A&T) and SAE work with finance and budget community and establish policy directives that allows product centers and PEO to use available funds within their areas first for cycle time reduction, then allow other PEO and product centers to use any remaining funds for cycle time reduction efforts, prior to initiating any new projects or project feature or requirement additions

Recommendation 5

Demonstrate Application and Results Through Near-Term Demonstration Projects

A demonstrated capability and impact of cycle time reduction efforts is needed at both the project and portfolio-of-projects levels before full implementation

5.1 Establish pathfinder projects that demonstrate the effectiveness of the cycle time reduction approach on specific projects

5.2 Establish Re-invention Laboratory that demonstrated effectiveness of approach on a range of products within an entire program office or product center

5. Demonstrate Application Through Demonstration Projects

Research Findings:

- **Very few projects ever complete early**
- **Funding-based issues are systemic across all projects**
- **Examples of similar commercial projects finishing in significantly less time**
- **Commercial constraints are significantly different than in defense industry**
- **Few previous efforts to reduce programmatic limitation on product development cycle time from which to base decisions**
- **Few demonstrated examples to show proper path to reduce cycle times as most important barrier to cycle time reduction**

Recommendation 5.1:
Establish Pathfinder Projects that Demonstrate the Ability to Reduce Cycle Time on Specific Projects

Research Findings:

- Few examples of cycle time reduction -- No clear demonstrated capability to shorten times
- Widespread skepticism about impact of cycle time reduction on cost and performance.

Recommended Actions - **Select and run a series of pathfinder projects that demonstrate the ability to reduce cycle time on a wide array of project types**

- Select a range of new and existing projects from all product centers as pathfinder projects to show results of a cycle time focus and cycle time reduction efforts
- Make direct comparisons with similar "control" projects not selected for the pathfinder status or cycle time focus
  - Capture data on results reported by all affected organization,
  - Compare to previously planned and resulting pathfinder approaches.
- Capture lessons learned and problems faced at the project level
- As lessons are becoming apparent, begin second round of Pathfinder project. (within 8 months)

Suggested Implementation Strategies

- OSD(A&T) and SAEs direct initiation of a series of pilot projects at each product centers
- Allow Pathfinders wide latitude to take actions they feel are appropriate to reduce cycle time

Recommendation 5.2:
Establish Re-invention Laboratory that Demonstrates the Effectiveness of Approach on the Acquisition System

Research Findings

- Product development cycle time affects not only each project but affects the development process as a whole
- The focus on cycle time in the commercial industry has been on a range of projects and not on one single project
- No demonstration has been conducted to account for compounding effects of cycle time reduction on a set of projects

Recommend Action

- Select a number of program offices with many development projects to act as reinvention Laboratories to demonstrate the compounding impact of cycle time focus on a range of development activities over time
- A basket SPO or a mature development project would have a large range of projects that could demonstrate the effectiveness of this approach within a controlled environment
- A matching program office without the re-invention lab could provide a control comparison to demonstrate effect of changes

Suggested Implementation Strategy

- OSD(A&T) and SAE direct the establishment of a SPO level Reinvention Laboratory at each product center

Near-Term Steps

Address the following recommendations

1.1 A clear business case or rational for cycle time reduction

2.1 Analysis and estimate of how long a development project

Planning Preparation — **1 - 6 months**

- **Making case and preparing plans**
- **Senior Leadership decision**

Develop Implementation Practices — **6 -18 months**

- **Develop Tools, Policies, and Procedures**
- **Pilots, Pathfinders, Tests**

Extra Back Up Slides

Proposed Implementation Process
(24 months)

Planning Preparation	**1 - 6 months**
– Making case and preparing plans	
– Senior Leadership decision	
Develop Implementation Practices	**6 -18 months**
– Develop Tools, Policies, and Procedures	
– Pilots, Pathfinders, Tests	
– Senior Leadership decision	
Initiate Wide Scale Implementation	**18 months**
Implementation Review	**24 months**
– Senior Leadership Review	

Major McNutt mcnuttr@af.pentagon.mil 4/13/99 cycletime37 ©1999 Ross McNutt

Planning Preparation
(1-6 months)

- Develop clear and compelling business case for cycle time reduction
  - Use existing cycle time reduction teams to develop business case
- Establish core cycle time reduction staff group (3 people full time)
- Plan schedule information collection method
  - ID all projects - Determine information needed
  - Prepare surveys - Select contractor to develop models
- Develop education plan for next phase
- Establish complete implementation plan for next phase
- ID pilot projects and develop implementation plans
- ID team capabilities required and members for next phase

- Present business case and plan for next phase to senior leaders for approval of next steps
- Get buy in and support from both Government and Industry Leaders

Major McNutt mcnuttr@af.pentagon.mil 4/13/99 cycletime38 ©1999 Ross McNutt

Develop Implementing Practices and Procedures
(6-18 months)

- Establish Government/Industry Team (Working (Gov/Cont Assigned) /Exec)
  - Establish "Schedule Proposal" structure and requirements
  - Define acceptable menu of schedule based source selection criteria
  - Define acceptable menu of schedule based contract incentives
- Establish Government Team (Working (Assigned) /Exec)
  - Define Requirements for Project "Should Take" Analysis
  - Define Project Screening Process, how to implement it, and get agreement
  - Determine how to implement with PPBS system and get agreement
  - Determine appropriate Government schedule incentives
- Implement training/Communication program across all organizations (1 full time)
- Execute schedule survey and develop schedule database tools (1 FTE +Contractor)
- Initiate Pilot Projects and pull early results/lessons learned (1 full time)
- Develop detailed implementation plans and options (who/how/when)(group)
- Test proposed procedures and practices on a number of sample projects

---

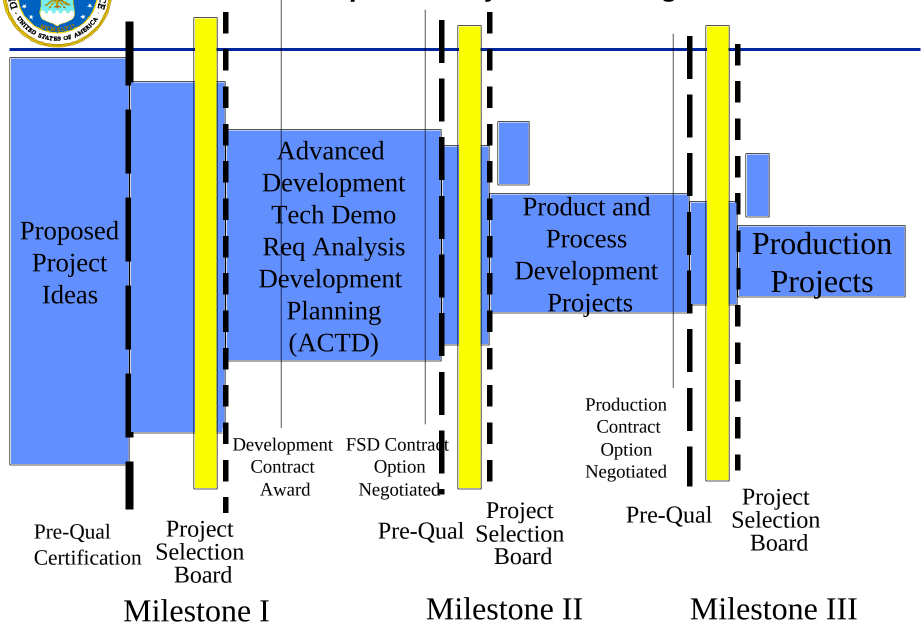
- Implementation plans reviewed by senior DoD and industry leaders
  - Achieve negotiated agreement at senior levels
  - Fully consult congressional and administrative leaders
- Make decision to implement new policies - Secretary of Defense/AF level

Full Scale Implementation
(Starting in 18 months)

- Implement plans and procedures
  - Change Regulations/Issue guidance
- Run Project Selection Board
- Execute project changes

- Review implementation progress at 6 month intervals

Proposed Project Screening Process Structure



Major McNutt mcnuttr@af.pentagon.mil 4/13/99 cycletime41 ©1999 Ross McNutt

Major McNutt mcnuttr@af.pentagon.mil 4/13/99 cycletime42 ©1999 Ross McNutt

Appendix 2

Impact of Long Development Times

Long development times impact the DoD in many ways. They impact our military capability through systems, long in development, not being ready when needed. They impact our military capability through systems' not meeting the current need when fielded. They impact our military capability through fielding of dated technology in our newest systems. They impact our ability to quickly respond to new or emerging threats or to respond to known safety issues. Long development times also result in increased cost to develop and sustainment of our weapon systems. Examples of each type of impact of long development times are provided below.

A. Systems Not Ready When Needed

Desert Storm provided a unique opportunity to identify military needs in a wartime environment and determine the possible impact of equipment in the development pipeline had it had been deployed more quickly. Seven systems would have mitigated critical needs during the early part of Desert Shield and Desert Storm.

Long-Range, Wide-Body Strategic and Tactical Airlift: The C-17

In the late 1970s, the Air Force identified a need for the C-17 to supply the newly formed U.S. Rapid Deployment Force. The request for proposals for the C-X cargo plane was released in October 1980. Eleven years later, during the earliest stages of Desert Shield and the Gulf War, a critical shortage of heavy-lift aircraft, combined with a lack of suitable airfields in Saudi Arabia, limited the speed by which the military buildup could occur. This was precisely the mission for which the C-17 was being developed and designed. The C-17 was delayed in part owing to a decision to produce more C-5B aircraft. The C-17 did not see its first operational use until Operation Provide Hope in Bosnia in 1995.[116]

Satellite Communications: MILSTAR

Development of the MILSTAR satellite system, designed to upgrade the military communication system, began in 1981. In 1983, the Air Force issued a contract designed to provide secure and survivable tactical and strategic communication by the late 1980s. Eight years later, the communication capacity required to conduct the early stages of Desert Shield proved inadequate, as existing UHF and SHF systems were susceptible to jamming and interference. Communication officers finally cobbled together an adequate communication system by employing leased commercial satellites, repositioning existing military satellites, and reviving decommissioned communication satellites.[117] The first MILSTAR satellite was not launched until February 1994, and the second satellite not until November 1995.

Precision Targeting: LANTIRN Targeting Pod

The Low Altitude Navigation and Targeting Infrared for Night (LANTIRN) system was initiated in 1979 to give F-16s and F-15s the ability to navigate at night and to lock onto targets precisely and use precision-guided weapons. During Desert Storm, 11 years into a 12-year development effort, only six targeting pods were available for F-15Es and no targeting pods were available for F-16s. This left most deployed fighters without precision bombing capability. This increased the number of aircraft required to attack each target, decreased the lethality of the attack, decreased the distance from the target the pilots could release the bombs, and exposed pilots to greater risk. Immediately after Desert Storm, the targeting pods were produced and fielded at a rate of 28 per month. By 1992, 400 F-16s were outfitted with the LANTIRN system, which had the development time been shorter may have been available for use in Desert Storm.[118]

Secure Data Links: Joint Tactical Information Distribution System

The Joint Tactical Information Distribution System (JTIDS) program was initiated in 1974 to enable all U.S. military fighter and command-and-control aircraft to share data on the

---

[116] Information provided by the C-17 Program Element Monitor and *several Aviation Week and Space Technology* articles from the early 1980s.

[117] Alan Campen. Ed. *The First Information War: The Story of Communication, Computers, and Intellegence Systems in the Persian Gulf War*. Armed Forces Communications and Electronics Association Fairfax VA. October 1992. Pg. 8.

[118] Information provided by the LANTIRN Program Office.

location of friendly and enemy aircraft and targets. During Desert Storm, 19 years into a 20-year development effort, no fighter aircraft were equipped with JTIDS. The results was less situational awareness for U.S. pilots, higher risk of fratricide, and the possible escape of additional Iraqi planes to Iran.[119] The system was first deployed in 1993 on the F-15s at Mountain Home AFB. In a matter of weeks, the fighter wing employed new tactics, using a line formation, that allowed a dramatic increase in effectiveness due directly to the increase in situational awareness provided by JTIDS.[120]

Satellite Navigation: The Global Positioning System

The satellite Global Positioning System (GPS) program was initiated in December 1973 to provide continuous worldwide, three-dimensional navigation ability to U.S. air, ground, and sea forces. At the beginning of Desert Storm, 21 years into a 23-year development effort, GPS could provide only 14 hours of navigation daily. Very little GPS receiver equipment was available to operators of aircraft, or vehicles, or to soldiers for personal use. Soldiers' parents purchased commercially available GPS receivers and sent them to their sons and daughters. The Japanese purchased American-made commercial GPS receivers for U.S. military personnel. By the end of Desert Storm, the launch of additional satellites provided 23 hours of navigation coverage, but many military units still did not have user equipment. The lack of GPS field receivers meant that more soldiers were lost in the desert and captured. The U.S. Army also attributed most fratricide incidents to armored units that were lost and out of position.[121] Because of the lack of available military receivers that could use the encrypted GPS signals, the U.S. had to provide the GPS signals without encryption and as a result did not have the capability of denying the use of the GPS system to Iraq while using the signal itself.[122]

The Advanced Medium-Range Air-to-Air Missile

The Advanced Medium-Range Air-to-Air Missile (AMRAAM) was initiated in November 1978 to give U.S. fighter aircraft an advanced radar system for guiding missiles. AMRAAM was designed to provide a multiple-target, fire-and-forget capability at extended range, expanding the engagement envelope over the Vietnam-era AIM-7 Sparrow missile. During Desert Storm, 12 years into a 13-year development effort, no operational AMRAAMs were available, although several missiles were used in tests. After Desert Storm testing was accelerated, and operational capability was declared six months later, in September 1991.

---

[119] Information provided by a former program director for JTIDS.
[120] Information provided by a former program director for JTIDS.
[121] U.S. Army report on GPS in Desert Storm.
[122] Information provided by the GPS Program Office.

Wide-Area Anti-Tank Cluster Bomb: The CBU-97B Sensor-Fuzed Weapon

Development of the Sensor-Fuzed Weapon (SFW) was initiated in January 1983, to provide the ability for a limited number of aircraft to destroy up to 24 tanks in a single attack. During Desert Storm, 8 years into a 14-year development program, no Sensor-Fuzed Weapons were available. The U.S. thus had limited capability to stop an early Iraqi armored invasion of Saudi Arabia had one occurred, and additional aircraft sorties were required to attack Iraqi armor, increasing the risk to pilots and destroying fewer Iraqi tanks.[123]

Many other major defense systems under development for at least five years were not available for use in Desert Shield or Desert Storm. Those included the Stingray Anti-Aircraft Missile, the V-22 Osprey, the AGM-130 Powered Glide Bomb, the Mark XV Identification Friend or Foe, the Army Brilliant Anti-Tank Weapon, the Advanced Apache Longbow and Hellfire Missile System, the Comanche attack helicopter, the AWACS Block 30-35 upgrade program, the F-22 air superiority fighter, and the B-2 strategic bomber. All these systems were started based on an identified need. Many of these systems have still not reached operational status 7 years later.

A few systems were rushed through development and made available to troops during the six months prior to Desert Storm. The Joint STARS surveillance plane was pushed into service and provided critical observations of Iraqi troop movements. A bomb system, the Bunker Buster, was developed and fielded in 29 days. This rapid action demonstrated that the acquisition system can move quickly to meet the needs of warfighters when they are seen as essential. But such efforts are the exception rather than the rule.

B. Systems Not Meeting Current Needs When Fielded

With the average development time for a new major defense system approaching 10 years, the need for and requirements of any system in development may dramatically change. Many of the systems now in the pipeline are based on the threat and political environment that existed before the dissolution of the Soviet Union and the Gulf War. Of 26 current major development programs in the RAND database and due for completion between 1995 and 1999, only 6 were started following the end of the Cold War. Twelve began during the early 1980s, when the U.S. faced a radically different environment. One result is that systems often do not adequately meet warfighters' current needs when fielded.

MILSTAR I

Communication is a significant area where new systems are not meeting today's requirements. During the early 1980s, for example, the most pressing need was seen as communication systems that could survive a full range of conflicts, from regional to full-scale nuclear war, and also foil enemy attempts to jam the signals. In response to these needs, the MILSTAR program was started in 1981. But by the time the first satellite was deployed in 1994, the requirements had changed dramatically. In the Gulf War, the most pressing problems were not security and anti-jam capabilities but bandwidth and the capacity to process data quickly. Even if MILSTAR had been operational in time for Desert Storm, its low data-processing rate would not have helped meet the large demand for fast communication. A significant portion of communication today is in the form of digital data and fax transmission, which MILSTAR's 2400-baud data rate does not effectively support. The development of MILSTAR consumed most of the available resources to upgrade and maintain other military satellite communication systems. The MILSTAR II satellite now in development is projected to increase the data-processing rate moderately, to 9600 baud, but even this new design will not be able to support communication needs as they existed during Desert Storm.[124]

C. New Systems Fielded with Dated Technology

In the time now required to develop and field a new military system, technology is no longer state of the art, and in some cases it is obsolete and out of production. Ten years ago, the Packard Commission stated that long development cycles "lead to obsolete technology in our fielded equipment. We forfeit our five-year technological lead by the time it takes us to get our systems from the laboratory into the field."[125] This problem is severely exacerbated by the rapid rate of advance in electronics. Technologies are usually selected and "frozen" early in full-scale development, significantly undermining programs based on fast-moving electronic and computing technologies. These effects can be seen in programs such as the F-22, Joint STARS, and AWACS Radar System Improvement Programs (RSIP), all of which are heavily dependent on computer processing. Current

---

[123] Information provided by the Wide Area Munition program element monitor and the Wide Area Munition Program Office.

[124] Campen, Alan. Editor. The First Information War: The Story of Communications, Computers, and Intellegence Systems in the Persian Gulf War. Fairfax Virginia: AFCEA International Press. 1992. Pg. 58.

[125] President's Blue Ribbon Commission on Defense Management. "A Formula For Action: A Report to the President on Defense Acquisition" (The Packard Commission Report). Washington D.C. April 1986.

processors available operate significantly faster. As a point of reference of today's (1998) technology used in home computers, the current Pentium II processor, operating at 300 MHz, can execute the equivalent of 627 million instructions per second (MIPS).[126]

AWACS RSIP

The initial computer processor for the AWACS Radar System Improvement Program, selected in 1986, was the most advanced then available--a specially modified R-3000 at 10-12 million instructions per second. In 1995, the production of the modified R-3000 was canceled so the processor was upgraded to a specially modified R-4400 at running at 33-50 MIPS--at an additional cost of $26 million. In 1998, the manufacturer again stopped producing the modified processor, and the Air Force made a $4 million lifetime buy to satisfy all its future needs for the processors for the expected life of the equipment. Now the service wants to upgrade to the Power PC processor to allow for additional capability, but no funds are available to pay for another upgrade.[127] The current processor is running at near capacity with the existing software modifications leaving little room for additional functions.

---

[126] Based on analysis of processor performance from Intel Corporation processor facts sheets from their web pages.

[127] Source: AWACS Program Office

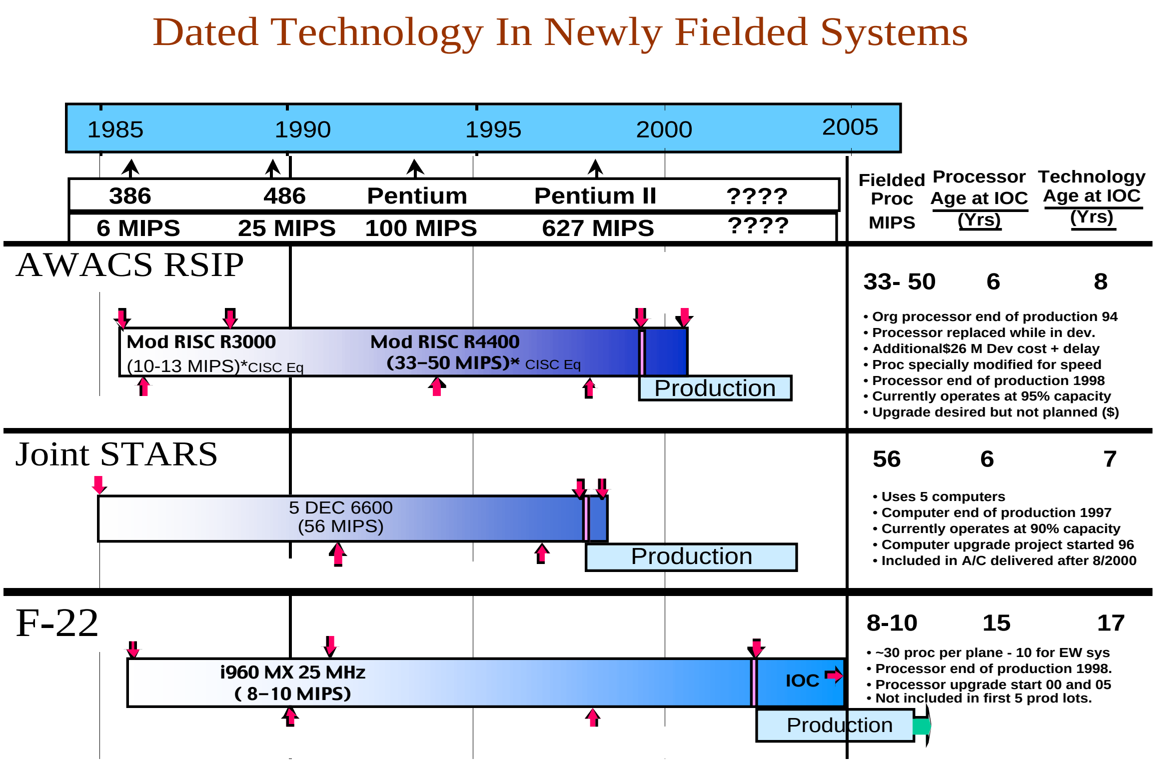


Figure A2-1: The Progression of Commercial Computer Processors vs. Those Fielded in AWACS RSIP, Joint STARS and F-22 Aircraft [128]

Joint STARS

The processor for the Joint STARS Main Mission computer was selected in 1991 as the DEC VAX 66D, running at 56 MIPS. The system required three active computers, three to run mission software and two to operate as ready spares. But the original processor is out of production. An upgrade program was started in 1996 that will replace the five computers with one operating and one spare processor, to be included in aircraft delivered in 2005 and later. The current fleet will also be upgraded.

The F-22

The F-22 processor, selected in 1990 as the best available technology, is the i960MX, which operates at 8-10 MIPS. The electronic warfare system requires 10 such processors to perform its mission. Today a single processor could provide the same capability. Because the supplier is ending production, the Air Force is making a final buy

[128] Source: F-22, AWACS, and Joint STARS Program Offices.

of the number required until an upgraded processor can be incorporated into the design of the aircraft. Processor upgrade programs are scheduled for 2000 and 2005, when the F-22 is expected to reach operational capability.[129]

Computer processors are not the only area of technology that is rapidly changing. Other areas include digital signal processors, memory, sensors, communication systems, autonomous control, and navigation technologies. Many of these technology advances are being driven by the rapid advances within commercial electronics. Military aircraft, ships, and space systems rely heavily on such electronic systems to provide communication and control.

D. Slow Response to New or Emerging Threats

Emerging threats based on new technology or a unique combination of existing technologies can pose a significant challenge to U.S. forces, and leave them exposed. Closing the performance gap and quickly developing counter-systems is an important aspect of maintaining technological superiority.

One example of the U.S. failure to pursue this strategy has been development of a counter-system to the Soviet Archer AA-11 off-boresight air-to-air missile. Off-boresight missiles can attack aircraft at a wider angle than standard air-to-air missiles, allowing aircraft equipped with them to fire on opponents at greater angles from the nose of the aircraft and significantly increasing their chances of killing their opponent before being shot down.

U.S. Response to Off-Boresight Air-to-Air Missiles

The United States learned of the Soviet AA-11 Archer off-boresight missile and its helmet-mounted cueing system in 1985, when it photographed Soviet fighters carrying the new missiles near Finland. In 1989, after the unification of Germany, the U.S. obtained access to many operational AA-11 missiles from the former East German Air Force. Analysis and flight tests of the AA-missiles and the cueing system in MiG-29s indicated a "very significant"

[129] Source: F-22 Program Element Monitor and F-22 Program Office.

combat advantage over F-16s in close air-to-air combat.[130] The Israelis minimized their exposure to the new Soviet missile by quickly developing and fielding a more capable off-boresight missile, which they tested within three years and had operational within nine years. Both the Russian and Israeli missile systems are now sold to a number of countries.[131]

The U.S. Air Force had long seen the significant advantage provided by off-boresight missiles in close air combat. Studies in 1970 of the F-15 and the proposed AIM-82 off-boresight missile showed a very dramatic effect with kill ratios increasing dramatically over similarly non-equipped aircraft.[132] The AIM-82 missile was never developed. In a 1995 article in *Aviation Week*, General Roland Yates, retired Air Force Materiel Command commander, said, "The off-boresight missile and helmet mounted cueing system dominates the close-in fight within 3 miles. If an enemy has the capability and you do not, he's going to kill you. If he can see you, you are dead. Even a 9 g turn will not make any difference."[133] A former senior Joint Chiefs of Staff officer stated, "For the Air Force and Navy not to have a helmet-mounted cueing sight and an off-boresight missile is absolutely criminal."[134]

The U.S. system developed in response to the new threat is the AIM-9X, which is expected to reach operational capability in 2002, 17 years after the threat was identified. Currently, no U.S. fighter has any off-boresight missile capability.

E. Slow Response to Known Safety Problems

The current development process is also often slow to respond to identified safety requirements. Two high-visibility programs that highlighted this slow response are the integration of Traffic Collision and Avoidance Systems and Global Positioning System receivers on military aircraft.

[130] "Missile Handicap, Part 1. U.S. Intensifies Efforts to Meet Missile Threat" *Aviation Week and Space Technology*. 16 October 1995. Pg. 36.
[131] "Missile Handicap, Part 1. U.S. Intensifies Efforts to Meet Missile Threat" *Aviation Week and Space Technology.* 16 October 1995. Pg. 36.
[132] The study was conducted by LTC Larry Welch in 1970 and was known as the TAC Avenger Study. It showed very dramatic advantages of off-boresight missiles. LTC Welch later became the Air Force Chief of Staff. It is detailed in the *Pentagon Paradox* by James Stevenson. Naval Institute Press. Annapolis MD 1993.
[133] "Missile Handicap, Part 1. U.S. Intensifies Efforts to Meet Missile Threat" AWST 16 Oct 1995. Pg. 36.
[134] Missile Handicap, Part 1. U.S. Intensifies Efforts to Meet Missile Threat" AWST 16 Oct 1995. Pg.36.

Traffic Collision and Avoidance System

The Traffic Collision and Avoidance System (TCAS) was first officially recommended for installation in Air Force aircraft in 1994 after a near collision among two B-52s on an around-the-world exercise and a Saudi Arabian 747 over the Mediterranean Sea.[135] Similar TCAS equipment had been previously ordered installed on all commercial transport aircraft in 1988. A safety officer implored that the equipment also be added to military aircraft after another near-miss in 1995, when a C-5 flew between a KC-10 and the flight of F-16s it was refueling.

After the crash of the T-43 (Boeing 737) carrying Secretary of Commerce Ron Brown in 1996, the Air Force was ordered to install the TCAS system on its aircraft. Installation on VIP transport aircraft is to be completed by 2001, and on larger transports, which carry troops and cargo, by 2006. This response came too late for the crews of a U.S. C-141 and a German C-130, which collided off the coast of Africa in September 1997, killing 33 people, including 9 U.S. service members.

GPS Receivers on Military Aircraft

The long development, purchase, and installation time in providing Global Positioning System navigation equipment on military aircraft has produced similar results. Commercial GPS receivers have been widely available. FAA-certified aircraft GPS receivers have been available for commercial and private aircraft for less than several thousand dollars per aircraft for many years. Portable handheld receivers with moving map displays and aeronautical databases designed for aircraft use are available for less than $600. The lack of GPS capability was cited as one of the contributing factors in the 1996 crash of a military Boeing 737 that killed Commerce Secretary Ron Brown, 34 business leaders, crew, and others. The pilot was off course on a non-precision approach and crashed into a mountain. It was found that GPS could have helped avoid the accident. Following the Brown accident GPS equipment was ordered installed on all military aircraft. GPS could have helped avoid other accidents as well including the crash of a C-130 presidential support plane in Wyoming which went off course at night and hit a mountain. The lack of GPS navigation also could have helped avoid an Army helicopter's inadvertently crossing the DMZ into North Korea; one of the pilots died and an

[135] Matthew Brelis and Stephen Kurkjian. "Ill Equipped Air Force Plane Haunts Widow." *Boston Globe*. December 3, 1997. Pg. 1.

international incident ensued when the North Koreans shot down the helicopter. GPS navigation has been in development since 1973 and has been commercially available since 1992. Integration of GPS systems into all military aircraft is not expected to be complete until after 2002.

F. Effects of Development Time on Cost

Long development times also impact the cost of the systems that we buy. They lead to higher development cost and less money being spent on producing the products.

Increased Cost of Development

Conventional wisdom indicates that the longer the development time, the more a project will cost. The Packard Commission concurred, stating that "time is money, and experience argues that a ten-year acquisition cycle is clearly more expensive than a five-year cycle."[136] There is significant evidence of this effect in commercial development efforts.[137] Unfortunately, no data estimating the cost of different development schedules are available for specific military projects. The cost models now used by DoD and the services do not account for the effects of time.

Data on major defense acquisition projects available from RAND show a positive correlation between development time and cost. Of the ACAT I programs, those that take less than 7 years to complete have an average development cost of $1.2 billion. Projects that take between 7 and 14 years have an average cost of $1.8 billion. Those taking over 14 years average $3.6 billion in development cost.[138]

[136] President's Blue Ribbon Commission on Defense Management. "A Formula for Action: A Report to the President on Defense Acquisition" (The Packard Commission Report). Washington D.C. April 1986. Pg.. 8.

[137] See discussion in Chapter 2.

[138] For the 123 projects in the RAND database with the necessary information, the Pearson correlation coefficient between the length of project schedules and cost of development is positive 0.25, with a two-tailed significance level of 0.005. This indicates that though there is considerable scatter in the data, longer programs on average do cost more.

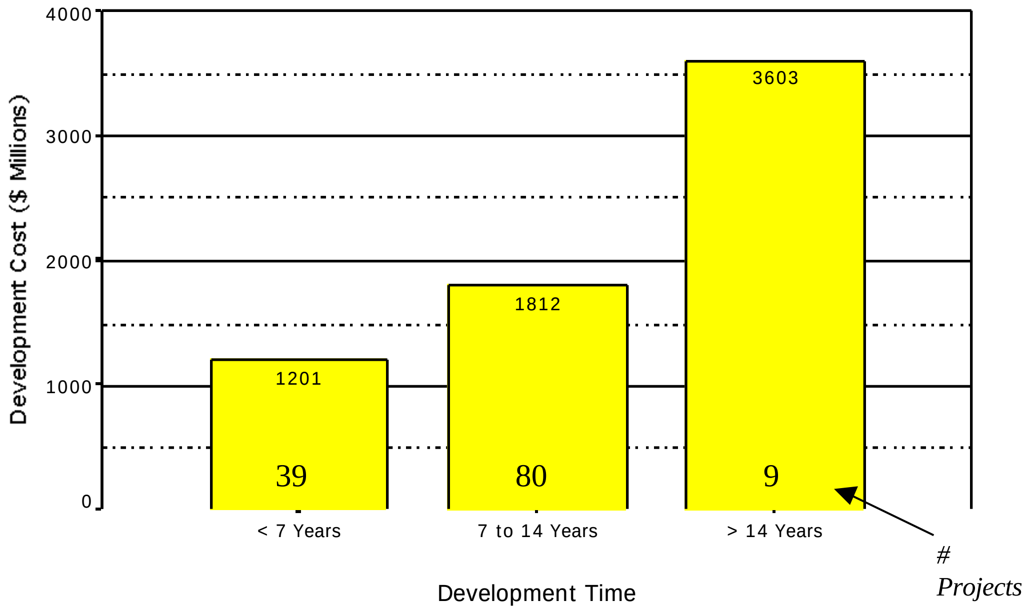


Figure A2-2: Cost by Years in Development for Major Defense Acquisition Programs (Data from RAND SAR Database).

Similarly, cost and schedule data on 154 projects of all sizes included in the surveys conducted as part of this research effort indicate that the correlation between development time and cost is both positive and statistically significant.[139] The best fit line through the development cost and the development time for the projects surveyed indicated that the development cost was best correlated with the fourth power of the development time.

$$\textbf{Dev Cost (\$M)} \sim \textbf{(0.03 x Dev Time (months) + 1.36)}^{\mathbf{4}}$$

[139] These surveys and the responses from them are discussed at length in Chapter 5-10.

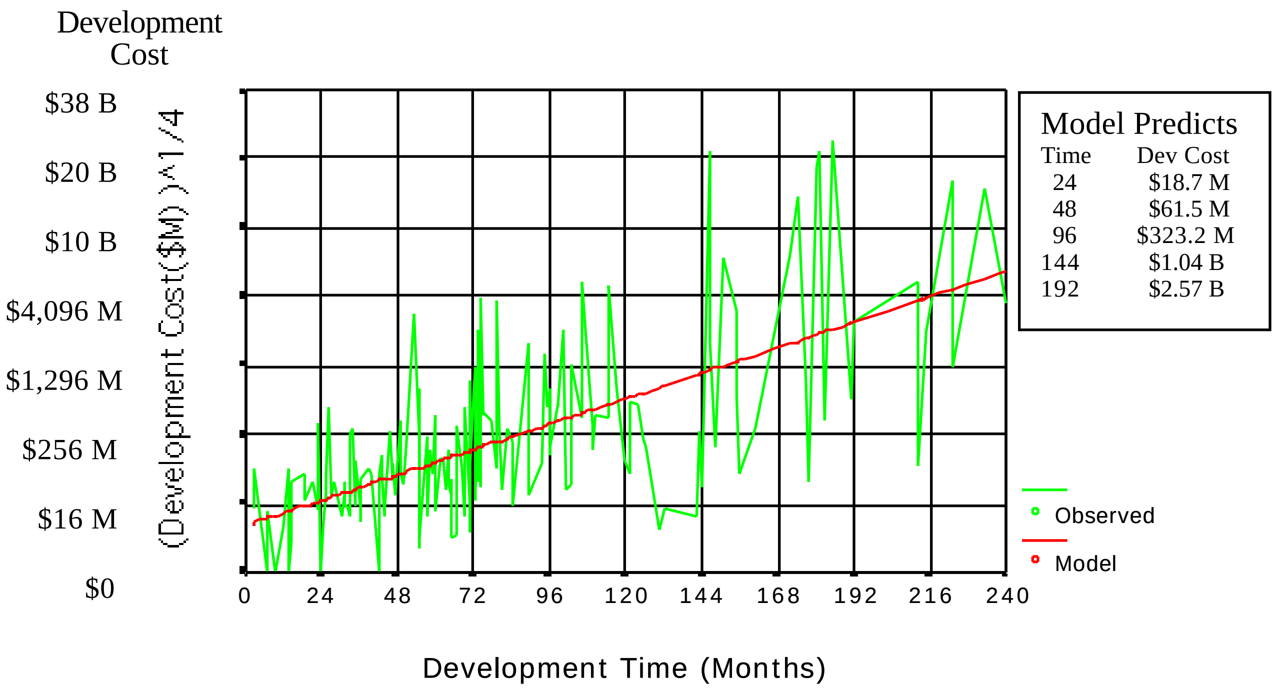


Figure A2-3: Plot of Development Cost and Development Time for 154 Projects Surveyed as Part of this Research. 4th-power Scale for Cost. Best Fit Line Drawn through Data.

This does not necessarily mean that a project scheduled to take longer than another will necessarily result in dramatic increases in development costs, only that across all projects, development cost is associated with the fourth power of the schedule. This relationship may be complicated by a host of factors other than simply long development times, including complex requirements for the weapons. Also, long development times may result in design changes in response to changing threats, technologies, and priorities, raising costs. However, the data does suggest that longer programs not only cost more -- they cost a lot more.

More Funds Towards Development – Less Towards Production

Not only do longer programs cost more to develop but a larger percentage of the total project cost is consumed during development. Data from the RAND SAR database indicate that projects requiring less than 14 years of development time saw 27 percent of their cost go to development and 73 percent go to production. Projects with development times over 14 years had 46 percent of their cost go to development and 54 percent go to production.

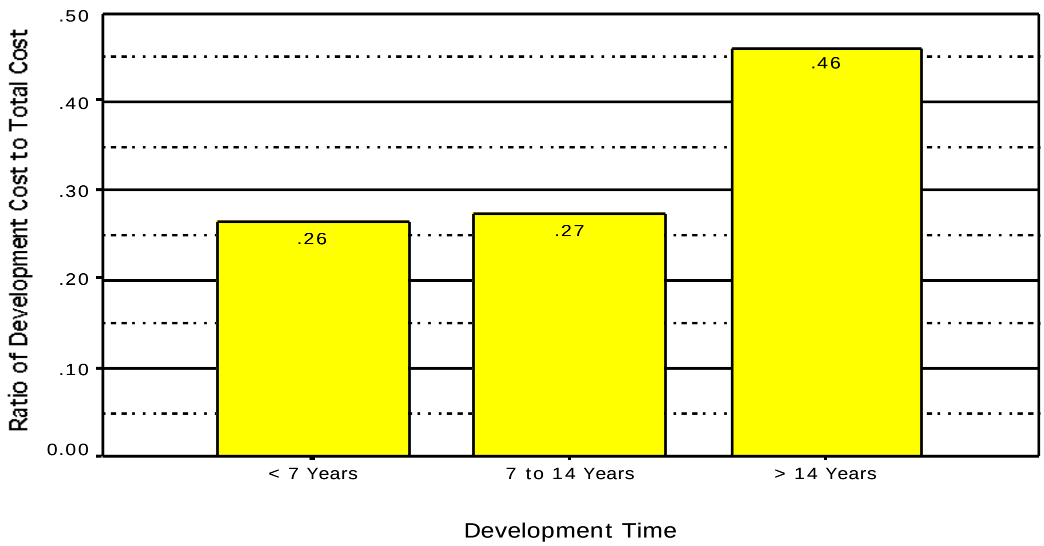


Figure A2-4: Ratio of Program Cost Going to Development and Production, by Development Time.[140]

As development programs have lengthened over the years, so has the percentage of DoD funding going to research, development, test, and evaluation (RDT&E). RDT&E funding for 1997 was $32 billion, representing 42 percent of total DoD investment funding (RDT&E plus production). This was the highest percentage ever. The rising percentage spent on RDT&E means that a smaller percentage is available for producing new systems or enhancing the operations, training, and readiness of existing forces. While both RDT&E and production funds have been cut significantly in the last 10 years, the RDT&E accounts have sustained smaller decreases. This has resulted in fewer new systems being fielded and made available for the warfighter.

[140] Source of Data: RAND SAR Database

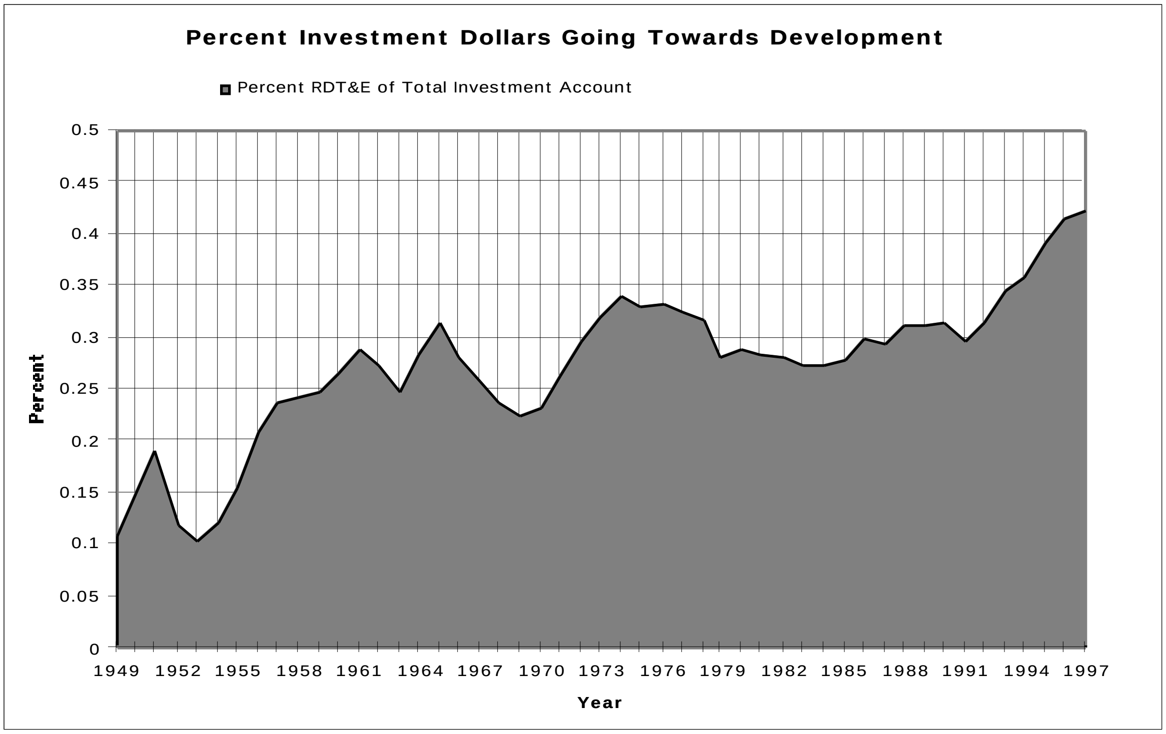


Figure A2-5: Percent of DoD Investment Dollars (RDT&E + Procurement) Going to Research, Development, Testing, and Evaluation.[141]

[141] Based on DoD Annual Budget.

Appendix 3

Air Force Product Development Process

Removed for brevity

Appendix 4

Surveys

Removed for brevity

Appendix 5

References

Air Force Acquisition Reform Online Newsletter April/March 1996. http://www.safaq.hq.af.mil.

Air Force Acquisition Reform Online Newsletter June/July 1996. http://www.safaq.hq.af.mil.

Air Force Policy Directive 10-6 Mission Needs and Operational Requirements 19 Jan 1993.

Air Force Policy Instruction 10-601Mission Needs and Operational Requirements Guidance and Procedures 31 May 1994.

Air Force Policy Directive 10-14 Modernization Planning 3 Mar 95.

Air Force Policy Instruction 10-1401 Modernization Planning Documentation 22 May 1995.

Air Force Policy Directive 16-5 Planning Programming and Budgeting System 29 July 94.

Air Force Policy Directive 63-1 Acquisition System 31 Aug 1993.

Air Force Policy Instruction 63-101 Acquisition System 11 May 1994.

Air Force Systems Command. "Affordable Acquisition Approach." Andrews AFB MD. 1983.

Air Force Systems Command. "Affordable Acquisition Approach Data Handbook, Volume 1". Andrews AFB MD. 1983.

Augustine, Norman R. Augustine's Laws. American Institute of Aeronautics and Astronautics. Washington DC. 1983.

Augustine, Norman. "From Industry … Acquisition Reform: Dream or Mirage." Army RD&A Magazine. September-October 1996. Pg. 20-22.

Boyd, Scott and Brian Mundt. "Schedule Estimating Relationships for the Engineering Development of Bomber, Transport, Tanker, and Surveillance Aircraft Systems." Thesis. Air Force Institute of Technology. Dayton OH. 1993.

Brelis, Matthew and Stephen Kurkjian. "Ill-equipped Air Force Plane Haunts Widow." Boston Globe. 3 December 1997. Pg. 1.

Buchfeller, Glenn. "Cost and Schedule Benchmarks for Defense Acquisition Contracts." Thesis. Air Force Institute of Technology. Dayton OH. 1994.

Campen, Alan. Editor. The First Information War: The Story of Communications, Computers, and Intellegence Systems in the Persian Gulf War. Fairfax VA: AFCEA International Press. 1992.

Clark, Kim, and Steven Wheelwright. Managing New Product and Process Development: Text and Cases. New York: The Free Press. 1993.

Clark, Kim, and Steven Wheelwright. Revolutionizing Product Development: Quantum Leaps in Speed, Efficiency, and Quality. New York:The Free Press. 1992.

Clark, Kim, and Takahiro Fujimoto. Product Development Performance: Strategy, Organization and Management in the World Auto Industry. Boston MA: Harvard Business School Press. 1991.

Clark, Kim and Takahiro Fujimoto. "Lead Time in Automobile Product Development: Explaining the Japanese Advantage". Journal of Engineering and Technology Management, Vol 6. Amsterdam, Netherlands. 1989. Pg. 25-58.

Clubb, Dean. "Blinding Speed Equals Competitive Advantage." Acquisition Review Quarterly Fall 1996. Volume 3, No. 2. Pg. 175-180.

Department of Defense. "DoD Cycle Time Analysis Tool." OSD(A&T) API. 15 January 1998.

Department of Defense. "Report of the Defense Science Board Task Force on Defense Acquisition Reform." Office of the Under Secretary of Defense for Acquisition. Washington D.C. July 1993.

Department of Defense. "Report of the Defense Science Board Task Force on Defense Acquisition Reform (Phase II)." Office of the Under Secretary of Defense for Acquisition and Technology. Washington D.C. August 1994.

Department of Defense. "Report of the Defense Science Board Task Force on Defense Acquisition Reform (Phase III)" Office of the Under Secretary of Defense for Acquisition and Technology. Washington D.C. May 1996.

Department of Defense. "Report of the Defense Science Board: 1991 Summer Study on Weapon Development and Production Technology." Office of the Under Secretary of Defense for Acquisition and Technology. Washington D.C. November 1991.

Department of Defense. "Report of the Defense Science Board: 1986 Summer Study on Use of Commercial Components in Military Equipment." Office of the Under Secretary of Defense for Acquisition. Washington D.C. January 1987.

Department of Defense. "Improved Defense Through Equipment Upgrades: The U.S. and Its Security Partners." Final Report of the 1984 Defense Science Board Summer Study on Upgrading Current Inventory Equipment. Office of the Under Secretary of Defense for Research and Engineering. Washington D.C. November 1984.

Defense Systems Management College. "Scheduling Guide for Program Managers." Defense Systems Management College Press. Ft Belvoir VA. May 1994.

"DoD Press Conference: SECDEF and DAE Jump Start Acquisition Reform Week at Pentagon Press Conference." March 14, 1997. Program Manager. Defense Systems Management College. May June 1997.

Dornheim, Michael. "U.S. Fighters to Get Helmet Displays after 2000." Aviation Week and Space Technology. October 23, 1995. Pg. 46-47.

Dornheim, Michael and David Hughes. "U.S. Intensifies Efforts to Meet Missile Threat." Aviation Week and Space Technology. October 16, 1995. Pg. 36-39.

Drezner, Jeffery A., Jeanne M. Jarvaise, Ronald Wayne Hess, Paul G. Hough, Daniel Norton. "An Analysis of Weapon System Cost Growth". The RAND Corporation. Santa Monica CA. 1993.

Drezner, Jeffery A, and Giles Smith. "An Analysis of Weapon System Acquisition Schedules". R-3937-ACQ. Santa Monica CA: The RAND Corporation. Dec 1990.

Edwards, Vernon. "Source Selection: The Competitive Proposals and Contracting Process. Course Manual." Washington. DC: Educational Services Institute and The George Washington Univerity School of Business and Public Management. 1994.

Follmer, Andrew. "How Can Research and Development Lead Time Be Reduced?" U.S. Army War College. Carlisle Barracks PA. April 1990.

Fox, J. Ronald. <u>Arming America: How the U.S. Buys Weapons</u>. Cambridge MA: Harvard University Press. 1974.

Gansler, Jacques S. <u>The Defense Industry</u>. Cambridge MA: MIT Press. 1980.

Gansler, Jacques S. <u>Affording Defense</u>. Cambridge MA: MIT Press. 1989.

Gansler, Jacques. "USD(A&T) Memorandum: The Single Process Initiative--A Long Term Perspective." 3 June 1998.

Hughes, David. "Luftwaffe MiG Pilots Effective with Archer." <u>Aviation Week and Space Technology</u>. October 16, 1995. Pg. 39.

Harmon, Bruce and Lisa Ward. "Schedule Estimating Relationships for Air-Launched Missiles," Cost Analysis and Estimating: Tools and Techniques (Proceedings of the Institute of Cost Analysis National Conference), Pg. 115-157. New York NY: Springer-Verlag. 1990.

Harmon, Bruce, Lisa Ward, and Paul Palmer. "Assessing Acquisition Schedules for Tactical Aircraft," Cost Analysis Applications of Economics and Operations Research (Proceedings of the Institute of Cost Analysis National Conference), Pg. 259-280. New York NY: Springer-Verlag. 1989.

Hazeldean Richard, and John Topfer. "Contracting for Schedule Performance: The Relationship Between Pre-contract Award Actions by the DoD and the Resultant Schedule Performance." AFIT Thesis. Wright-Patterson AFB OH. 1993.

Irvine, James. "Soviet Weapons-System Acquisition." China Lake CA: Naval Weapon Center. 1991.

Jarvaise, J.M., J.A. Drezner, and D. M. Norton. "The Defense System Cost Performance Database: Cost Growth Analysis Using Selected Acquisition Reports." MR-625-OSD. Santa Monica CA: The RAND Corporation. 1996.

Kaminski, Dr. Paul G. "Advanced Concept Technology Demonstrations: Challenges and Opportunities" Keynote Address, ACTD Manager's Conference. DSMC. Fort Belvoir VA. Sept 10, 1996.

Kaminski, Dr. Paul G. USD(A&T) Memorandum. "Policy on Cost-Performance Tradeoffs" (CAIV). July 19, 1995.

Meyer, Christoper. "Lessons From Leaders: The Evolution of Speed in Industry." Briefing. Lean Aircraft Initiative Plenary Session. Hartford CN. September 1997.

Meyer, Christopher. <u>Fast Cycle Time: How to Align Purpose, Strategy, and Structure for Speed.</u> New York: The Free Press. 1993.

Nachmias, David, and Chava Frankfort-Nachmias. Research Methods in the Social Sciences . New York: St, Martins Press. 1987.

Nash, Ralph and John Cibinic. Competitive Negotiation: The Source Selection Process. Washington DC: George Washington University National Law Center. 1993.

Nelson, Eric. "Independent Schedule Assessment FSD Study." Contract F33657-85-D-0064. Fairborn OH: The Analytical Sciences Corporation, 30 June 1986. (TR-5300-2-2).

Nelson, Eric and Trageser, Jay. "Analogy Selection Methodology Study." The Analytical Sciences Corporation. Fairborn OH. Contract F33657-82-D-0064. 1 December 1987. (TR-5306-7-2).

Norusis, Marija. SPSS. SPSS 6.1 Base System User's Guide, Part 2. Chicago IL: SPSS Inc. 1994.

Perry, William. "Memorandum for Secretaries of Military Departments. Subject: Reducing Cycle Times." Secretary of Defense. Washington D.C. 14 Sept. 1994.

Perry, William. "Secretary of Defense Memorandum: Common Systems/ISO-9000/Expedited Block Changes." Dec 6, 1995.

President's Blue Ribbon Commission on Defense Management. "A Formula for Action: A Report to the President on Defense Acquisition" (The Packard Commission Report). Washington D.C. April 1986.

President's Blue Ribbon Commission on Defense Management. "National Security Planning and Budgeting. A Report to the President on Defense Acquisition" (The Packard Commission Report). Washington D.C. June 1986.

President's Blue Ribbon Commission on Defense Management. "A Quest For Excellence: A Report to the President on Defense Acquisition" (The Packard Commission Report). Washington D.C. April 1986.

Przemieniecki, J.S. Editor. Acquisition of Defense Systems. Washington D.C.: American Institute of Aeronautics and Astronautics. 1993.

Snedecoir George W., and William G. Cochran. Statistical Methods. 8th ed. Ames IA: Iowa State University Press. 1989.

Rebentisch, Eric. "Managing With/Under Program Instabilities." Lean Aircraft Initiative Phase I Research report. Massachusetts Institute of Technology. Cambridge MA. 1996.

Rees, D.G. Essential Statistics. 3rd Ed. New York: Chapman and Hall. 1995.

Reig, Gailey, and George Weber. "A Study of the Relationship Between Initial Production Test Articles in a System Development Program and the Success of that Program." DSMC Press Technical Report TR 2-95. Defense Systems Management College. Ft. Belvoir VA. May 1995.

Rothman, M.B. "Aerospace Weapon System Acquisition Milestones: A Database". Contract MDA903-85-C-0030. Santa Monica CA: The RAND Corporation, October 1987 (N-2599-ACQ).

Smith, Preston G. and Donald G. Reinertsen. Developing Products in Half the Time. New York: Van Nostrand Reinhold. 1995.

Smith, Giles and E. T. Friedman. "An Analysis of Weapon System Acquisition Intervals, Past and Present." Contract F49620-77-C-0023, MDA903-78-C-0188 Santa Monica: The RAND Corporation, November 1980. (R-2605-DR&E/AF).

Stevenson, James Perry. The Pentagon Paradox: The Development of the F-18 Hornet. Annapolis MD: Naval Institute Press. 1993.

Tyson, Karen, Richard Nelson, Om Neang, and Paul Palmer. "Acquiring Major Systems: Cost and Schedule Trends and Acquisition Initiative Effectiveness." Contract MDA903-84-C-0031. Alexandria VA: Institute for Defense Analysis. March 1989. (P-2201).

Wandland, Klaes, and Gary Wickman. "Analysis of Cost and Schedule Growth on Sole Source and Competitive Contracts." Thesis. Air Force Institute of Technology. 1993.

Whelan, John. Cases and Materials on Federal Government Contracts. Mineola NY: The Foundation Press. 1985

Womack, James P., Daniel T. Jones, and Daniel Roos. The Machine that Changed the World: The Story of Lean Production. New York: Harper Perennial. 1990.